THE LIVERWORTS
BRITISH AND FOREIGN

By SIR EDWARD FRY, G.C.B.

AND

AGNES FRY

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BY

THE RIGHT HONOURABLE

SIR EDWARD FRY, G.C.B.,

WITH THE ASSISTANCE OF

AGNES FRY

Ἐν πᾶσι γὰρ τοῖς φυσικοῖς ἐνεστὶ τι θαυμαστὸν.
ARIS. *de partibus animalium*, I. c. 5.

" Natural things are glorious, and to know them glorious."
TREHERNE *Poet. Works*, p. xxv.

LONDON:

WITHERBY & Co., 326, HIGH HOLBORN, W.C.

1911

BY THE SAME AUTHOR:

BRITISH MOSSES.

New and Revised Edition. Illustrated.

Crown 8vo. 1s. 6d. net.

PREFATORY NOTE.

This little book is intended as a companion volume to a small essay on British Mosses, of which the second edition appeared in 1908.

The quotation from Aristotle on the title page may be thus translated : In all natural things there dwells somewhat of the marvellous.

In the systematic names of species I have, in the case of British species, followed wherever possible the nomenclature of Mr. Macvicar's "Revised Key to the Hepatics of the British Isles" ; in all other cases that of the "Synopsis Hepaticarum" of Gottsche, Lindenberg and Nees ab Esenbeck, 1844.

The illustrations are from drawings by my daughter Agnes Fry, and, except where otherwise indicated, are from nature.

I have to thank Sir Joseph D. Hooker for his cordial approval of the use I have made of a few illustrations from "The British Jungermanniceæ" and the "Musci Exotici," of the late Sir William J. Hooker ; Mr. W. Ingham, of York, for the identification of some specimens; and my daughter, Agnes Fry, not only for the drawings, but for zealous co-operation in every part of this little book.

E. F.

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THE LIVERWORTS.

I. Introductory.

The subject of this little volume is a group of plants, not very conspicuous, nor to every one very familiar, but common, and, in some cases, very elegant, and in all cases very interesting. The casual observer of them would probably call them Mosses, and the appellation would not be far wrong, for though they are not Mosses in the narrower sense, they belong to the wider group of Moss-like plants.

The Muscineæ, or Mosses, and Moss-like plants (also called the Bryophyta), consist of three groups separable from one another—first and highest, the Musci, or true Mosses, or, as they are sometimes called from the urn-like form of their spore cases, the Urn Mosses; secondly, the Sphagnaceæ, or Peat or Turf Mosses; and lastly, the Hepaticæ, or Hepatics, or Liverworts, the group with which we are to be concerned. The name was first given to a species of this group by Micheli, an Italian botanist of the early eighteenth century, from some supposed resemblance to a liver. The name is, however, unfortunate; first, because there is a genus of flowering plants well known in our gardens bearing the same name, derived, no doubt, from a supposed likeness between the lobes of their leaves and the lobes of the liver of animals; and, secondly, because this peculiar form characterizes only a small part of the class.

Of the three groups which I have mentioned, the true Mosses are in many respects the most highly organized, and must be regarded as the crown and glory of the whole family; whilst the Liverworts are in some ways the most lowly in their organization, and may be regarded as the probable ancestors of their more illustrious descendants. The Peat Mosses are in several respects intermediate between the Liverworts and the Urn Mosses.

What are the differences which separate the three groups from one another, we shall hope to consider later on.

If you take in one hand a seaweed or a piece of the green floating Alga from a mill-stream, and take in the other any flowering plant—let us say a buttercup—and compare the two, one of the most striking differences will be this: that, whilst the buttercup is plainly differentiated into stem and leaves, there is no such differentiation in the case of the Alga. In the one case the leaves and stem are clean-cut, sharply-defined organs; whereas in the other case the vegetable structure is more or less indefinite in its mode of growth and does not present the same clear distinction into two parts. This difference is a very marked one, and the whole Vegetable Kingdom may be divided into two great groups by reason of it. To the vegetable structure without clear differentiation into stem and leaves the name of Thallus is given by botanists, and to the clearly differentiated stem the name of Corm is given by some botanists, and the two great groups to which I have alluded have been called respectively Thallophytes and Cormophytes. It is a matter of great interest to trace the change from one of these forms to the other. Now amongst the Liverworts some are Thalloid in form; others are Cormophytic.

The distinction between the two classes will be clearly seen if my reader will compare Figs. 1 and 4. In the former we have a Liverwort with a thallus closely applied to the soil and with no leaves; in the latter we have another Liverwort with a stem and leaves which remind one of a flowering plant; but in both cases it will be observed that the fructification is similar. Thus, as some Liverworts are Thallophytes and others Cormophytes, we shall have an opportunity of watching, as it were, the transition from one group to the other and of taking note of certain intermediate forms. All the Algæ, unless we include the Characeæ amongst them, are Thallophytes; and even the Characeæ, whilst they are differentiated into a primary axis or stem, and secondary axes or branches, have these branches repetitions in structure of the primary axis or stem, so that there are no true leaves. In the Liverworts

we may notice two things—one, the first appearance of true but very simple leaves; the other perhaps the most highly developed form of thallus.

This distinction between the two forms of Liverworts is so fundamental that it is necessary to describe the two groups separately. The groups are sometimes known respectively as the Thallose, or Frondose Liverworts, and the Foliose Liverworts. The following table of families will be useful for reference as we proceed:—

LIVERWORTS.

Thallose or Frondose	Riccieæ Monocleæ—part of Anthocereæ Marchanticæ Jungermannieæ—part of
Foliose	Monocleæ—part of Jungermannieæ—part of

Thus it will be seen that the line of cleavage between the two great groups runs not only through the Liverworts but through the great and numerous family of the Jungermannieæ and the very small family of the Monocleæ.

Applying the generally received doctrine of evolution, no one can hesitate to regard the Liverworts and Mosses as closely related groups, or can consider the Liverworts as other than the earlier and simpler group from which the Mosses have possibly been derived; and there are strong reasons to believe that the line of development has been from the Liverworts through the Sphagnaceæ or Peat Mosses to the Musci or Urn Mosses. "Alone amongst the Mosses the embryo of Sphagnum segments by successive transverse walls, like a Liverwort."* And, again, when the germination of a spore of a Peat Moss occurs not in water but on damp earth, it produces a prothallus closely resembling the plants either of Blasia or of Anthoceros; and certain other points of similarity have been observed in the structure of the antherids and antherizoids and in the absence of a true calyptra or veil on the spore case.

The Liverworts present, as will appear more plainly

* Bower, "Origin of Land Flora," p. 272.

as we proceed, a great variety and a very wide divergence of form, and it is not easy to present a single view of the whole family or to give a definition of it. In this respect there is a wide difference between the Mosses and the Liverworts, for whilst the Mosses are with slight exceptions a compact and well-defined class, the Liverworts are a loose group, difficult to bring under any single type, and varying greatly in their general appearance. In fact, the Liverworts present to one's mind the idea of a crowd of organisms which have not made up their minds in which line they shall go, and which are trying experiments in all directions to see which is best for them to take. Their neighbours and relatives above and below are evidently the true Mosses on the one hand and the Algæ on the other.

From the true or Urn Mosses the whole group of Liverworts are separated by several characteristics, and first by the form of the spore-case. This, in the true Mosses, is a very definite urn-shaped organ, which is found under a considerable diversity throughout the whole group. On the other hand, whilst the forms of the spore-cases in the Liverworts are very numerous, they never possess a spore-case of the type of the true Mosses. Again, the spore-cases of the Mosses are covered by a delicate membrane known as the calyptra or veil (or *coiffe* of the French botanists), which is the upper part of the archegone, or fertilized female cell, borne up by the ascending stalk of the spore-case ; whilst in the Liverworts the archegone bursts to let the spore-case through, but all its broken pieces retain their original position.

From the true Mosses the whole group of thallose Liverworts are, as is evident, separated by very obvious differences of appearance, and when we come to consider the leaves of the foliose Jungermanniceæ, we shall see that there are differences between the leaves of the two groups.

When we turn to the other boundary line of the Liverworts and attempt to draw the distinction between them and the Algæ, the task becomes more difficult by reason of the very simple structure of some of the Liverworts, like the Riccia, and the great variety of form and organization and of the modes of reproduction of the Algæ.

A difference between the upper and the under sides—the dorsal and ventral surfaces—of the plant is present in the Liverworts, but is absent in many, if not in all, the Algæ. The free floating fronds of a seaweed are surrounded by the same medium and exposed to the same conditions on all sides, and the only differentiation in structure occurs between the adhesive and the floating parts of the Alga; and even in the land Algæ there is rarely, if ever, any structural difference between the lower and the upper surfaces of the plant. But, as I have said, in the Hepatics the case is different. In the thalloid forms, which alone approach the Algæ, the under and upper surfaces differ both in structure and function, the under surface developing rootlets and the upper surface a chlorophyllose layer, and usually the organs of reproduction.

The great diversity of the forms of the Liverworts makes it difficult to know how most easily to introduce them to a reader unacquainted with the subject. On consideration, I believe that I shall best perform my part by first taking two typical forms and explaining them, so as to make my reader familiar with terms which I shall be obliged to use; then by treating separately each of the principal groups, and afterwards gathering together a few observations as the result of that survey.

A thallose Liverwort.—First, I will take as an example of the thallose Liverworts, the *Pellia epiphylla* (Fig. 1), a very common plant affecting various situations—sometimes growing under water, sometimes on sand, and more often by the sides of streams or ditches, and in other damp situations. The forms which it assumes in these different habitats differ considerably; but the one depicted is a very frequent one on damp soil.

The thallus (*a a*) grows flat, or nearly flat, in large and dense patches, on the ground to which it is attached by root hairs (*b b*) which grow from the under surface, and especially from the midrib. The lobes of the thallus are from one to four inches in length, of a more or less oblong figure, and irregularly divided; of a deep green colour, sometimes tinged with purple towards the obscure midrib which the frond presents. The lobes of the thallus advance

from the growing point, which is an apical cell (c c) sunk in a recess between the lobes (d d), and when the plant is putting out its new lobes, the frilled appearance of the frond makes the plant very different in appearance from its earlier and later forms. This thallus of the Pellia has no true epidermis and no air cells or stomata; the parenchymatous cells of the interior are scarcely modified on either the upper or the lower surface, and the actions of

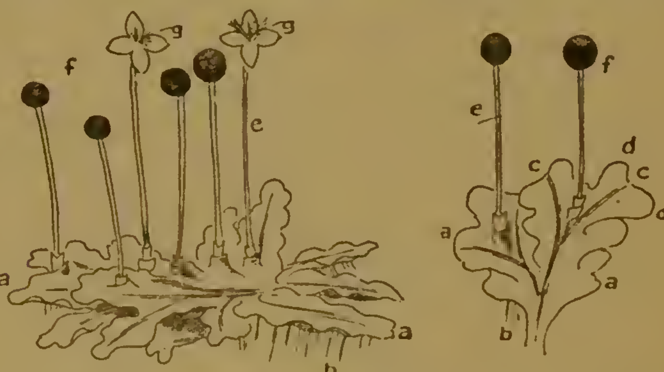

FIG. 1.—PELLIA EPIPHYLLA (*slightly magnified*); *a a*, thallus; *b b*, rootlets; *c c*, growing points between the lobes *d d*; *e e*, pedicels of the spore-cases; *f f*, spore-cases—some before, some after opening; *g g*, elaters.

respiration, absorption and exhalation appear to be performed through the delicate cell walls of the upper surface of the frond. On the whole, this vegetative structure of the Pellia is very like the prothallus of a Fern.

On the upper surface of this thallus of the Pellia (Fig. 2) may be seen, both in spring and autumn, small dots on either side of the midrib. These are very minute globular bodies, attached by a slight thread to the subjacent tissue. These bodies are known as antheridia, or antherids (Fig. 2*a*), and may be compared with the stamens of flowering plants. From each antherid comes, at its maturity, a mass of small spiral bodies, known as antherizoids (or spermatozoids) which may be compared with, and play the part of, the pollen of a flowering plant. To one point of this spiral body are attached two long and delicate hairs or cilia (Fig. 3*a*).

FIG. 2.—PELLIA EPIPHYLLA. After Sir Wm. J. Hooker. *A*, male frond showing the antherids; *B*, unfertilized archegones or female cells; *C*, showing the young capsule emerging from the involucre. (*All magnified.*)

Besides these antherids, the thallus of the Pellia produces the female organs also, which arise in great numbers towards the ends of the lobes of the thallus and behind the growing point, and thus towards the end of the midrib (Fig. 2*B*). Each group of archegones, as these organs are called, is wrapped in a kind of pocket known as the involucre (*C*). The archegone (Fig. 3) consists of the ovum, or female cell, and a flask-shaped vessel containing it (*c*), which is pierced by a narrow canal (*d*). Down this canal an antherizoid moving with a rotatory motion in the dew or rain finds its way, unites with the nucleus of the ovum and effects that marvellous change in it which we know as fertilization.

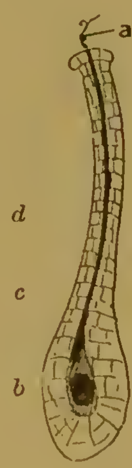

FIG. 3.—DIAGRAM OF ARCHEGONE; *a*, spermatozoid about to enter the canal of the archegone; *b*, ovum; *c*, cell; *d*, canal.

From the fertilized ovum is developed what I may call the fruit;

at first there appears a small green ball on the surface of the thallus, covered with a thin membrane. This grows upwards, bursts the membrane, and at last appears as a round body of a dark colour on the top of a translucent stalk (Fig. 1 *e e*). That round body is known as the sporangium, or sporogonium or sporogone, or spore-case or capsule; whilst the supporting stalk is known as the seta. In course of time the spore-case opens along four lines of division, and the surrounding wall is thus turned into four valves or leaves, sometimes called petals, and by their opening the spore-case discloses two organs—first, a set of delicate pellucid tubes with a spiral thickening, known as elaters (*g g*), and lastly, the object of all this development, the spores, which are to carry on the race to a new generation (see Fig. 1).

It may be well to mention that according to the language of botanists these thalloid plants rest on their stomachs, the upper surface being often spoken of as the dorsal and the lower surface as the ventral.

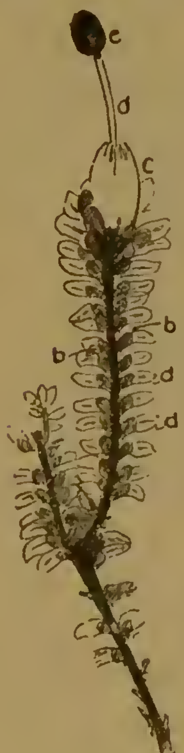

FIG. 4.—DIPLOPHYLLUM ALBICANS (*magnified about* 3½ *diameters*); *a a*, leaves; *b b*, small lobes of leaves; *c*, involucre; *d*, pedicel; *e*, spore-case.

A Foliose Liverwort.—Fig. 4 represents a common species of foliose Liverworts known as *Diplophyllum albicans*. If my readers will compare it with Fig. 1, they will see, as already mentioned, that the two plants depicted agree in the form of their fructification (for they both belong to the same chief family) whilst they differ most markedly in two important particulars; first, that instead of a thallus this plant has distinct stems

and branches and distinct leaves; and, secondly, that instead of cleaving to the dust like the thallus of the first form, this plant sends its stems upwards and aspires towards the air of heaven.

The figure shows the little plant terminating in an erect stem surmounted by a pitcher-like group of leaves of a very special form, from which rises a delicate stem crowned by the capsule which contains the spores. This pitcher-like organ is known as the perichætium.

The essential organs of reproduction in this plant are the same as in the thalloid form of Liverwort. We have again the antherids, the antherizoids, the archegone, and the sporogone; but here the antherids are found, not embedded in a thallus, but arising very inconspicuously in the axils of the leaves, and the spore-case arises, not from any thallus, but at the end of a branch.

Alternation of Generation.—Reference will be found in several of the following pages to two generations of Liverworts—the oophytic, or gametophytic, and the sporophytic. In order that my reader may follow these references, it is desirable here to state that botanists hold that the life-history of most plants, and conspicuously of Liverworts, Mosses and Ferns should be divided into two generations—the one beginning with a spore and ending in the production of a fertilized ovum, the other beginning from the fertilized ovum and ending in the production of spores. So, to take the case of *Pellia epiphylla*, if we start with a spore, we shall find that it produces the thallus on which grow the archegones and antherids, which by their union produce a fertilized ovum; this portion of the life-history is the oophytic, or gametophytic, generation. The fertilized ovum produces the seta, and the spore-cases and the spores; this portion of the life-history is described as the sporophytic generation. A further discussion of the matter will be found on a later page.

With this preliminary sketch of two specimens of the family and explanation of terms I hope that my reader will more easily follow what I have to say as to the different families, which will be found to contain a great variety of vegetable forms.

II. Riccieæ.

Referring to the table given on an earlier page, it will be seen that the family of the Riccieæ is placed at the head of the thallose Liverworts, not because of its high but rather because of its simple organization.

If we turn from the two species of Jungermannieæ, which I have briefly described, to this family, we shall be struck by the great diversity between the two.

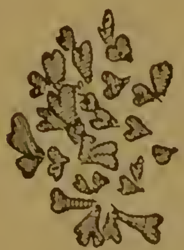

FIG. 5. — RICCIA SORACARPA (*slightly magnified*).

The most characteristic members of this family appear at first sight as little more than small flakes of green tissue; sometimes they live on the surface of damp ground (Fig. 5); sometimes they float on the water (Figs. 6 and 7), these aquatic species sometimes reproducing themselves in the water, sometimes only when they reach the damp earth. Linnæus placed these little plants (with Blasia) at the head of the Algæ, and

FIG. 6.—RICCIOCARPUS NATANS (*natural size*).

Dillenius, the great student of Mosses and Lichens, who was his contemporary, figured some species of this family as Lichens.

The structure of the little green flake is in reality not so simple as might be supposed. Fig. 8 represents a vertical section of *Ricciocarpus natans*, an aquatic species. At the top will be observed a thin layer of epidermal cells, beneath

which is a very loose cellular tissue, then comes a layer of smaller cells, charged with oil, and below that a series of coloured bracts, which have been converted into air chambers, and no doubt assist the little organism to float upon the water. In the body of the loose tissue will be observed two spore-cases, the one immature and the other ripe. These organs thus rest in the body of the thallus, and not on pedicels above it.

FIG. 7.—RICCIELLA FLUITANS (*magnified* 3 *diameters*).

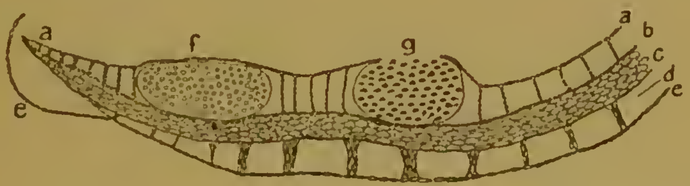

FIG. 8.—RICCIOCARPUS NATANS: section (*magnified* 15 *diameters*); *a a*, superior epidermis; *b*, loose tissue; *c*, tissue containing oil; *d*, and *e e*, coloured bracts forming an air layer; *f*, unripe sporangium; *g*, ripe sporangium.

In this group the development of the antherids and archegones is very similar to that which I have already described in *Pellia epiphylla*. Both organs arise from superficial cells on the upper surface of the thallus, and remain either bedded in or slightly raised above the surface. Sometimes both organs are on the same plant; sometimes on distinct plants. The result of the union of the two elements is a small spherical body with thin walls and no distinction of base or apex, which also rests on the surface of the thallus and produces the spores from which new plants arise.

We have here the two separate generations, the oophytic or gametophytic, represented by the thallus and its organs of reproduction, and the sporophytic by the spherical spore-case in closest connection with the thallus. Probably no simpler forms of oophyte and sporophyte than these can be found in the whole range of the vegetable kingdom, and they may probably be safely regarded as very primitive forms.

To this group of the Ricciciæ are referred two curious forms, both aquatic in habit.

Ricciella.—The one is the little *Ricciella fluitans* (Fig. 7), which, as its name indicates, floats on the water, and often in intricate masses, mixed sometimes with duck-weed and sometimes adhering to the under surface of water lilies. It fruits only when it has reached the damp ground on the margin of the water or when this has dried up.

Riella.—The genus Riella presents the second remarkable form to which I have referred.

This genus was until a few years ago constituted by seven species of the Mediterranean or European areas, but recently species have been found in Turkestan, Texas, the Grand Canary, and South Africa. I shall confine my description to the *Riella helicophylla*, which has in lieu of the flat horizontal thallus a frond in the form of a continuous spiral round an axial stem—a form, so far as I know, peculiar to this genus. Fig. 9 shows both the male and female plants of this species. In the female a succession of bracts along the stem support the archegones and subsequently the capsules. In the male plant the membranous wing is edged by a row of antherids. The whole anatomy of this plant is beautifully shown in the Atlas, vol. III., of the "Exploration Scientifique de l'Algérie,—Botanique." One of the few sites known for this plant, which grows in the water, was a spot on the shores of the Lake of Geneva; and a few years ago I made inquiry after it from Monsieur Correvan, a well-known botanist of that city, and found to my disappointment that the spot had been desecrated by the builder and the plant had disappeared.

This plant must be as beautiful as it is singular. "Figure to yourself," writes Montagne, the botanist, who

first described it, "an axis consisting of a nerve round which is wound in a most regular and elegant spiral a membranous wing of the width of five millimetres, of the most beautiful

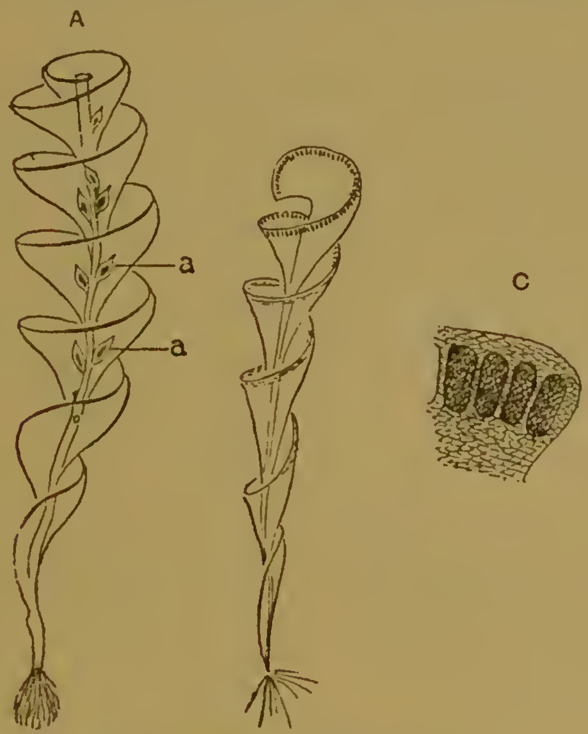

FIG. 9.—RIELLA HELICOPHYLLA.

A. Female plant with sporangia } (*magnified about* 2½
B. Male ,, ,, antherids } *diameters*).
C. Margin of male plant much magnified to show antherids.
From "Exploration Scientifique de l'Algérie," Paris, 1849.

green and of extreme delicacy, in such manner as to form with it a kind of gimlet or helix in inverted cones."

One of the most interesting points about the Hepaticæ as a whole is, that in them we have not only the change from a thallose to a foliose form of vegetation, but also the transition from a horizontal to a vertical attitude; and one of the early attempts (if I may use such an expression) to effect this change is to be found in this Riella—the

thallus assuming the position of an inclined plane, intermediate, therefore, between a horizontal and a vertical position, and the axis round which the plane revolves being vertical.

This experiment was made under the most favourable circumstances, that is to say, with water as the environment. Such a plant being no doubt of nearly the same specific gravity as the water, is able, as it were, with very little effort to grow against gravity. It is nearly as easy to grow upwards as downwards or horizontally; whereas for a plant on the earth to support itself against the force of gravity, some solid support, some hard skeleton is necessary, and we know what kind of skeleton is developed to meet the case of a high towering tree. The difference between these two media impresses itself on both the vegetable and the animal kingdom. The huge fibreless structures, like some of the sea-weeds—Caulerpa, for instance—

> " . . . . the oozy woods which wear
> The sapless foliage of the ocean."

or vast boneless form like the great jelly-fish, can keep themselves together in the supporting environment of the water, but would have short shrift if they attempted to live on solid earth and environed only by the air.

This experiment of the Riella to get up in the world does not seem to have been a great success. As already mentioned the genus consists only of a few species, and all of these are rare, and may, I suppose, easily disappear from the earth, or, rather, the water. It has, so far as I know, no near relatives, and furnishes the rare instance of a vegetable assuming the form of a screw or helix, though a spiral arrangement of leaves on a stem and the spiral form of some seed vessels are of familiar occurrence.

III. Monocleæ.

I have followed many earlier writers in treating the genera Monoclea and Calobryum as constituting a separate family.

The history of the genus Monoclea in botanical literature

is curious and suggestive. When, in 1820, Sir Wm. J. Hooker published the second volume of his "Musci Exotici" he included in it the description of a plant, his only authority for which were specimens in the herbarium of a Mr. Lambert, which had been collected by Forster when he went round the world with Captain Cook, and which he appears to have named *Anthoceros univalvis;* but which Hooker published under the name of *Monoclea Forsteri.* The provenance of the specimens was vaguely indicated in the herbarium as "Insulæ australes."

It was not until the year 1858 that this description by Hooker received any confirmation, and then amongst a small collection of Liverworts from the mountains of Chili, sent to Dr. C. H. Gottsche, he found a specimen of this Monoclea, which he fully described; and again of late years it has been found repeatedly by Professor Douglas H. Campbell, in the wet mountain ravines and the dripping rocks of Jamaica, and has been carefully examined by him.

The genus Monoclea has this one well-established species, *M. Forsteri* (Fig. 10) and two doubtful species, *M. dilatata* and *M. Gottschei*, and therefore the whole family may be said to rely on a single species. That plant stands apart from all the other Liverworts except Calobryum in the character of its sporange. At first sight the plant suggests to us now, as it seems to have done to Forster, the genus Anthoceros, of which more hereafter; but it stands distinguished from that by the facts (1) that the sporange opens not by two slits, but by a single opening—hence the name Monoclea of Hooker; and (2) that it possesses no columella. The plant bears the antherids and archegones on separate individuals. The antherids are developed much as in the Marchantieæ (of which hereafter). The thallus has neither nerve nor areolation nor air cells (*lacunæ*), all which are found in the Marchantieæ, and in lieu of the ventral scales of Marchantieæ it has papillate scales: it has root hairs of two forms—thin and thick walled respectively. Professor Campbell thinks that the affinities of the Monoclea are with the lower forms of Marchantieæ.

Fig. 10, copied from the drawing published by Dr. Gottsche, shows the general appearance of the plant seen on its two surfaces, and there will be observed no less than nine flask-shaped vessels, of which three, having been fertilized, have sent up spore-cases.

FIG. 10.—MONOCLEA FORSTERI. After Gottsche. *A*, dorsal surface; *B*, ventral surface.

Fig. 11, copied from Sir Wm. J. Hooker's drawing, shows the opening of the spore-case by a single valve, and the mass of spores and elaters being thereby let loose. Fig. 11*b*, also after Hooker, shows the spores and the elaters, which here end in a point and not in an open or blind end, as is sometimes the case.

The affinities of Monoclea are somewhat puzzling; in some respects it approaches most nearly to the great family of the Jungermanniæ; in others to the Marchantieæ.

The other genus of this family—Calobryum—is equally small, and consists of only one species, rare in the mountains of Java, where it was found by Blume, whence the specific

name, *Blumii.* It agrees with Monoclea in having a capsule opening by a single valve and having no columella, and hence is placed in the same family; but it differs in that it has not a thallus, but leaves, both cauline and involucral; the leaves are described as "folia per paria approximata, decurrentia, succulenta."

Thus in this small group of two genera we have that transition from Frondose to Foliose growth which is so noteworthy in the great family of the Jungermannieæ; and the plants with a single valve to their capsules, like those with four valves, possess the two distinct forms of vegetative growth. It would seem as if in each of these two groups there had been separately taken an upward step in development; and the line of division between Thallophytes and Cormophytes, of which we have spoken, thus runs through the very small family of Monocleæ, and the very large family of Jungermannieæ. This is an interesting case of what is to be observed in many groups, both of plants and animals, viz., that families which appear to have separated from one another nevertheless pursue somewhat parallel lines of development and reach corresponding stages or resting places. The great groups of placental and marsupial quadrupeds offer several of such similar stages in development.

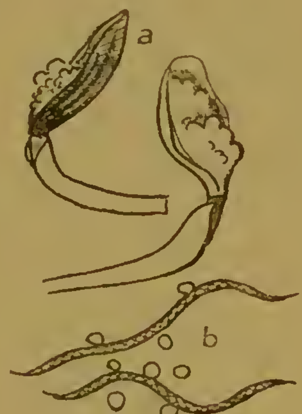

FIG. 11.—MONOCLEA FORSTERI. After Sir Wm. J. Hooker. *a*, spore-cases opening by a single valve; *b*, spores and elaters (*magnified*).

IV. ANTHOCEREÆ.

Closely akin to the Monocleæ is another small group of Liverworts of a character very remarkable, both in outward form and in minute structure. The Anthocereæ, so called from the principal genus Antho-

ceros, is a group so peculiar that it has been suggested that it ought to be separated from the Liverworts and placed as a separate or co-ordinate group between the Liverworts and the Ferns or their congeners. There are three genera in the group—of which one only, Anthoceras, is found in the British Islands — and that numbers only three species, none of which is common. *Anthoceros lævis* is depicted rather above natural size in Fig. 12, and it will be seen to consist of a thallus, with a long ascending spore-case, possessing a columella (*i.e.*, a central pillar) and opening by two valves. The plant is occasionally found on moist banks and sometimes produces numerous sporangia from the same thallus.

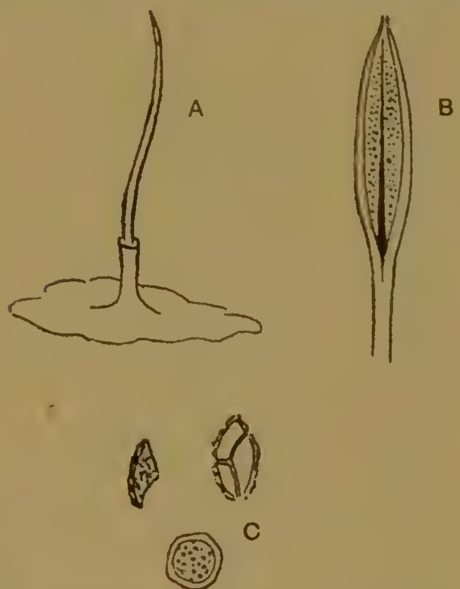

FIG. 12.—ANTHOCEROS LÆVIS; *A*, general view (*magnified slightly*); *B*, sporo-case magnified, showing columella and spores; *C*, spores (*magnified*).

A marked peculiarity of the thallus is found in the manner in which the colouring matter is disposed. In some cells the chlorophyll may be seen gathered round the cell walls, either forming a continuous line or as separate bodies, but other cells, instead of possessing many diffused grains of chlorophyll, have a so-called chloroplast, a large flattened plate of colouring matter, which encloses the nucleus of the cell, and when the cell divides, divides with the nucleus. A similar arrangement is found in some of the Algæ and in Selaginella, but is by no means common.

The under surface of the thallus emits small rhizoids or rootlets, and in many species presents openings or clefts

leading to cavities filled with mucilage, which offer a home to an Alga known as Nostoc (Fig. 13). This Nostoc is one of the so-called Blue-green Algæ, and appears in the form of irregular-shaped gelatinous masses, in which are seen under the microscope delicate filaments in the form of intertwined necklaces. This Alga seems to have a habit of associating itself with other vegetables of a higher type and is found to enter these clefts on the under side of the thallus of the Anthoceros, and there to establisd itself in colonies of sufficient size to be seen by the nakoh eye. It is also known to establish itself in the roots of Cycads, but it is unknown what is the exact physiological relation between the principal plant and the guest (whether invited or uninvited).

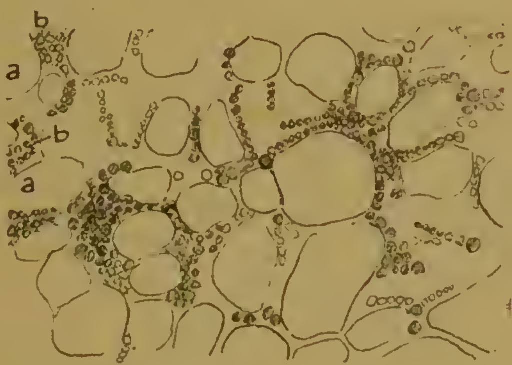

FIG. 13.—ANTHOCEROS LÆVIS; section of the thallus (*magnified* 360 *times*) showing *a a*, parenchymatous cells; *b b*, colonies of nostoc.

The thallus is of a very simple structure. It produces both archegones and antherids, which in their mode of cell-growth are found to differ very considerably from that of other Liverworts. They are both sunk in the body of the thallus, and even when fertilized, the archegone scarcely rises above the surface. The fertilized archegone throws up the long slender structure shown in Fig. 12—a structure not clearly differentiated into seta or stalk and spore-case, but producing spores nearly throughout its whole length, and opening at maturity by two longitudinal slits, splitting

not all at once along its whole length, but gradually, with the ripening of the spores. The mature structure consists of, first, the enclosing skin; next, a square sectioned columella or little pillar running the whole length of the spore-case; thirdly, of the spores, and lastly of certain sterile cells, which are rather the promise of elaters in some other organism than elaters themselves.

Round the base of this spore-case is a tube or sheath, which keeps pace with it in its early growth, and then, ceasing to grow as rapidly as the spore-case, forms only a sheath for its base. No doubt this tube represents, in part at least, the perichætium as we know it in the other Liverworts.

An examination of the minute structure of the wall of the spore-case shows that it possesses cells arranged to form an epidermis, accompanied with stomata of a form closely resembling that known in the flowering plants, a pore between two guard cells, which communicates with well-developed air chambers in the substance of the tissue.

Now here there are several points of interest to note. First, we notice the coincidence of the stoma with an epidermis, as we shall see it in Marchantia; next, we may notice that whilst in that plant the stomata are found on the gametophyte, here they occur on the sporophyte, that in that respect they recall the fact that in the Mosses the stomata where they occur are also found on the sporophyte; further, we may note that this seems one of the very earliest appearances of stomata in the sporophytic generation; and, lastly, the columella is well worthy of our attention. For whilst it is common amongst the true Mosses, it is found in this family alone amongst the Liverworts, and its absence is thus almost a mark of distinction between the two groups.

V. Marchantieæ.

Marchantia polymorpha, which I shall first take as the typical species of the family of the Marchantieæ, is a common plant, to be found in damp places, in yards or on old walls, and sometimes it makes its appearance in flower pots in greenhouses. It may be recognized

in spring and summer by the presence on the thallus of little open circular receptacles full of gemmæ, and of little palm or umbrella-like growths of two differing forms. The plant will repay a most attentive study.

In the *Marchantieæ* we come across a structure much more complicated than that of the Ricceæ. We have a thallus flat and ribbon-shaped, often branching dichotomously, often furnished with a midrib—and consisting of four distinct layers, to be hereafter described.

The ordinary prothallus of a fern is a single plate of cells, with cushions formed by a duplication of the cells in parts of the under surface for the support of the archegones and antherids, and with rootlets, but without epidermis, without stomata, and without air spaces. Contrasted with

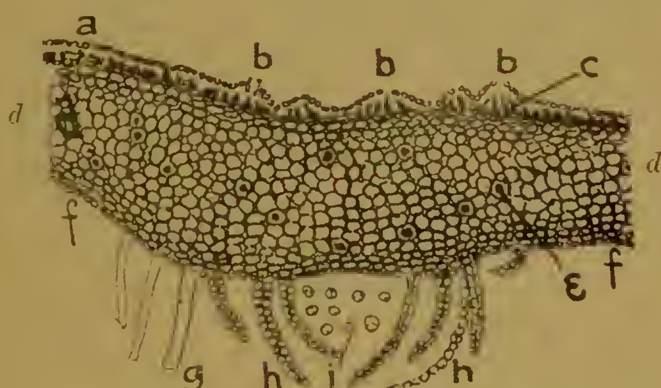

FIG. 14.—MARCHANTIA POLYMORPHA; vertical section of thallus (*magnified*); *a*, superior epidermis; *b b*, stomata or breathing pores, and underneath lacunæ or empty air chambers containing c, chlorophyllous cells; *d d*, parenchymatous tissue; *e*, amygdaloid bodies; *f f*, inferior epidermis; *g*, rhizoids; *h h*, scales arching over and protecting *i i*, trabecular tubes or water pipes.

such a thallus, that of the Marchantia appears as a highly complicated structure, and probably represents one of the highest points reached in the development and differentiation of parts in a thallus. Fig. 14 represents a longitudinal section of part of the thallus. Fig. 15 represents

more largely magnified a smaller portion of a like thallus. Proceeding from the upper or dorsal surface we observe, first, the layer of small cells (*a*) which constitute an epidermis and probably more or less prevent the immediate action of the atmosphere on the subjacent tissues. The plant, therefore, is provided with stomata or breathing pores, raised above the level of the epidermis, and leaving below them (*b*) vacant spaces, no doubt in the nature of lungs. In these cavities are found confervoid cells packed with chlorophyll (*c*), which is absent or rare in other parts of the thallus.

FIG. 15.—MARCHANTIA POLYMORPHA; a portion of the section in Fig. 14 (*magnified* 135 *diameters*): the same lettering applies.

Below the breathing cavities comes a body of parenchymatous tissue, devoid of chlorophyll (*d d*), amongst which are often found amygdaloid bodies or specialized cells (*e*), some charged with mucilage and others with a peculiar oil.

Then next in order come the cells of the epidermis of the lower or ventral surface (*f f*), and from this ventral surface are found growing rhizoids—or roots consisting of long simple tubular cells (*g*); and scales (*h h*) which arch over and protect the system of water pipes (*i i*) with which the plant is furnished in a way to be hereafter mentioned.

There are some points about the thallus which I have been unable to show in these sections: first, the upper surface of the thallus is divided into diamond-shaped areas, the

centre of each of which is a pore or stoma (compare Fig. 17); secondly, the mesial line of the thallus is marked by something like a midrib, which serves as a kind of hinge for the two sides of the thallus, which in times of drought move upwards towards one another, and so check the excessive transpiration of moisture. Lastly, a modification of the thallus forms receptacles for the male and female cells placed on stalks and somewhat like umbrellas in their form.

So interesting appears to me this plant that I am about to run the risk of wearying my reader by going further into detail on many of the points of structure which I have already briefly indicated.

It is evident that the stomata and the air chambers below them will cease to perform their functions of respiration if they are filled with water, and Nature therefore makes provision against this danger in a great variety of ways—sometimes by their position on the under side of the leaf on plants too high above the ground to favour the deposition of dew on the under surface, sometimes by the rolling of the leaf, somctimes by hairs or cuticular outgrowths. In the Marchantia this end is effected by the fact that the stoma opens on the top of a little mound or dome-shaped elevation, and that wax is produced by the adjoining cuticle (see Fig. 15).

I conceive that Marchantia and Anthoceros present some of the earliest instances in the ascending scale of vegetable life of the presence of an epidermis and stomata; they are scarcely if at all found in the Algæ, and only imperfectly in the Riccieæ, and the structure of this thallus of the Marchantia is far more like the structure of the higher forms of leaf, as in the flowering plants, than it is like the structure of the leaves of Mosses or of the thallus of the Ferns. Stomata, which thus present themselves in the Marchantia, are to be found only very rarely in the Mosses (chiefly near the spore-cases); they are absent from the fronds of the Filmy Ferns, but appear abundantly on the stems and fronds of the other ferns and are almost everywhere present in the leaves of flowering plants.

In the simple thallus of the Riccia and in the leaves of

the Mosses and many of the Liverworts, all the operations of the absorption and emission of fluid and gaseous bodies which occur in the life of the plant seem to take place from every part of the surface of the simple layer of cells, and through the thin walls of these cells. But in Marchantia we come upon a much more complex arrangement, special organs being provided for the purposes of absorption and respiration. We thus see the reason for the co-existence of stomata with the epidermis.

Conocephalus conicus (*Fegatella conica*), a frequent denizen of damp lanes and shady woods, and easily recognized by the fragrant odour it emits, is a near relative of the Marchantia, and its breathing pore is very similar to that of Marchantia, but in some ways less elaborate. Fig. 16 shows a section of the thallus through a stoma: at the

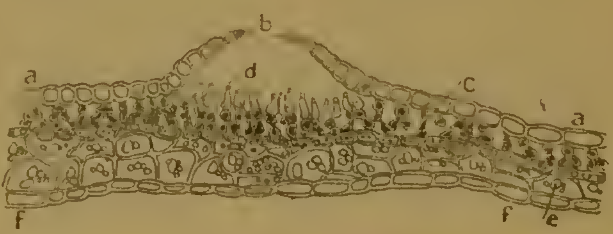

FIG. 16.—CONOCEPHALUS CONICUS; vertical section through a stoma; *a a*, superior epidermis; *b*, opening of the stoma; *c*, layer of chlorophyllous cells; *d*, flask-shaped cells in the air chamber below the stoma; *e*, cells containing oil; *f*, inferior epidermis. (*Magnified* 60 *diameters.*)

top the epidermis will be seen lifting itself to form a dome-like structure pierced by a hole—like a tiny model of the Pantheon at Rome; next come the cells containing chlorophyll; surmounted under the dome by a special row of flask-shaped cells, which, no doubt, are specially employed in respiration.

Next in descending order we come on a layer of cells carrying oil globules, to which is due the odour of the plant, and lastly, we note the inferior epidermis. Fig. 17 is a view looking up into the dome of a stoma of

Conocephalus and shows the way in which the ordinary epidermal cells are modified as they approach the actual aperture, and shows also some amygdaloid cells in the boundary line between the ordinary and the modified cells.

I now return to the Marchantia, and consider its arrangements for reproduction, which are two-fold—sexual and asexual. Asexually the plant is reproduced by gemmæ.

FIG. 17.—CONOCEPHALUS CONICUS; epidermis of a polygonal area of the thallus, looking up into the dome of a stoma; *a a*, ordinary epidermal cells; *b*, modified cells round the stoma; *c c*, oil globules round orifice; *d*, amygdaloid bodies. (*Magnified* 60 *diameters.*)

The gemmæ in Marchantia are contained in little receptacles growing abundantly on the upper surface of the thallus, which, with the contained gemmæ, look like small nests with eggs in them. In Lunularia, another common genus of this group, the containing receptacle is shaped like a crescent moon (from which I suppose the genus derives its name). The gemmæ originate from papillæ in the body of the receptacle and are gradually developed by cell division. Fig. 18 shows the course of the development of gemmæ in Marchantia.

It has been found that whichever side of these lenticular gemmæ be placed near the ground, it will develop the

structure which characterizes the ventral surface, and whichever side be placed uppermost, will in like manner give rise to the structure proper to the dorsal surface.

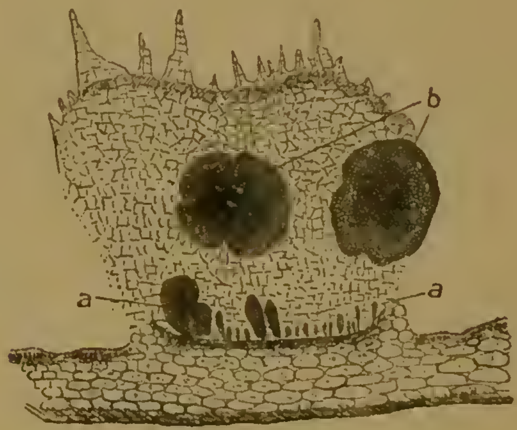

FIG. 18.—MARCHANTIA POLYMORPHA; section of a receptacle of gemmæ, showing gemmæ developing at base *a a*, and fully developed gemmæ escaping, *b b*. (*Magnified* 40 *diameters*.)

FIG. 19.—MARCHANTIA POLYMORPHA; diagrammatic section through half a male disc; *a*, epidermis; *b*, chlorophyllous cells; *c c*, cavities containing antherids, one cavity vacant; *d*, parenchyma; *e*, water tubes; *f*, scales on inferior surface. (*Magnified about* 16 *diameters*.)

Each side has the capacity to produce the one structure or the other, according to its situation and the resulting influences.

The sexual apparatus of the *Marchantia polymorpha* is two-fold. The thallus of the male plant turns upwards in the form of a thick stalk, surmounted by a fleshy disc, with an undulated margin (Fig. 19), and in the substance of this are found cavities opening by pores on the upper surface. Each of these cavities contains an antherid, a sac from which proceed the antherizoids, which are hair-like cells; these escape through the pores and in the presence of water find their way to the female cells. The antherids ripen and give forth the antherizoids, not all at the same time, but in succession, beginning with those nearest the centre of the disc and ending with the more peripheral, an arrangement by which the period of fertilization is obviously prolonged.

The structure I have described is often known as an antheridiophore

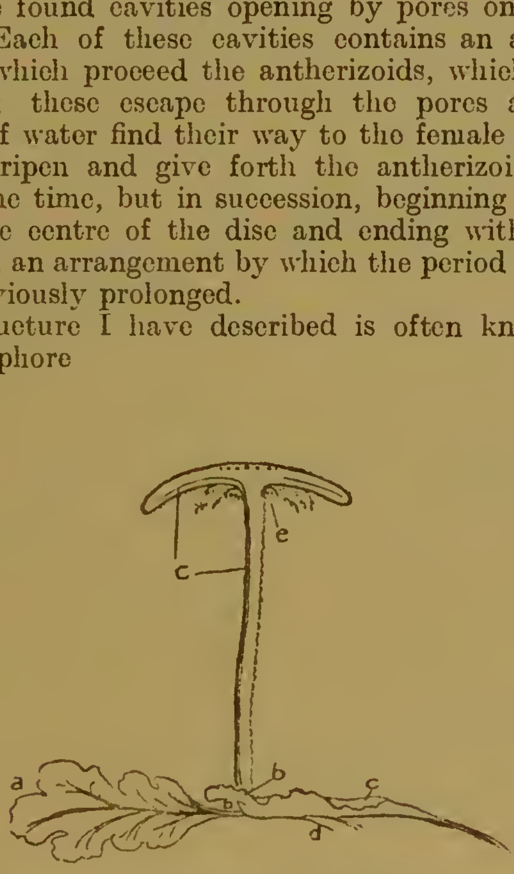

FIG. 20.—MARCHANTIA POLYMORPHA; diagram of thallus and archegoniophore; *a*, growing lobe of the thallus turned upwards to show the system of water tubes on the under surface; *b b*, section shown in Fig. 24; *c*, water tubes passing along the finger of the disc and descending the stalk; *d*, water tubes reaching the soil; *e*, archegones on under side of disc.

The thallus of the female plant likewise turns upward in the form of a stalked disc, a disc furnished with a margin of radial projections (Fig. 20); below and between each pair of rays the disc bears a perichætium, *i.e.*, the wrapper or involucre of a sporogone or female cell, which, when fertilized by an antherizoid, produces a mass of cells accompanied by elaters (Fig. 21). The archegone itself thus becomes the spore-case. These female organs are variously known as discs, receptacles or inflorescences, and the whole structure as an archegoniophore.

FIG. 21. — MARCHANTIA POLYMORPHA. Fertilized head of female plant; *a a*, capsules and elaters: magnified.

The stalks on which these discs, both male and female, arise, take their origin at the extremity of the mesial line of a lobe of thallus, as shown in Fig. 20, and after they have grown, the thallus advances by developing a lateral lobe (*a*).

Inasmuch as the antherids open on the upper surface of one disc and the archegones are placed on the under surface of the other disc, and inasmuch as the several discs seem generally to grow far apart and also attain about the same height at maturity, it is not very easy to see how the fertilization takes place. So far as my observations have gone, they lead me to think that many archegones are never fertilized. There is no doubt that water is the carrier of the antherizoids, but how this passes from one plant to another I do not know.

If now, without previous knowledge, we make a section of the stalk of either a male or female disc, we shall meet with a surprise. We are accustomed in stalks or stems

or pedicels to find some kind of concentric growth ; but here we find nothing of the kind. Fig. 22 will show us what, in fact, we shall find—the figure representing a section of the stalk of a female disc near the middle. The surface of the stalk turned towards the thallus (*a a*) consists of a series of epidermal and chlorophyllous cells, whilst the surface of the stalk turned away from the thallus displays two cavities formed by overlapping horns, constituting tubes running throughout the whole length of the stalk and themselves containing lesser tubes of a peculiar structure, forming part of the complex system of waterworks to be mentioned later.

FIG. 22.—MARCHANTIA POLYMORPHA, horizontal section, across the stalk of female disc ; *a a*, epidermis on dorsal side ; *b*, chlorophyllous cells beneath ; *c*, parenchyma ; *d d*, scales of ventral surface modified to form canals ; *e*, water tubes contained in the canals. (*Magnified* 170 *diameters*.)

The explanation of this curious structure is this : It is not a separate organ ; it is, in fact, only a continuation of the thallus ; the epidermis at the right of the figure (*a a*) is only a continuation of the epidermis of the thallus ; the parenchyma next to it is a continuation of the parenchyma of the thallus, and the horns which form the canals are only modifications of the scales of the lower surface which we saw in Fig. 14*h* and the enclosed water tubes are only continuations of the tubes which we saw protected by the scales. I have spoken of the epidermis of the stalk as a continuation of that of the prostrate thallus : this is not quite accurate, as there is a tract at the bottom of the stalk clear of epidermis.

Fig. 23 will further help to explain the structure of the archegoniophore. It is a section of one of the arms or fingers of the disc, and shows that this is also only a modified form of thallus : except for a brief space at the bottom, the structure is surrounded by epidermis ; then comes the

parenchyma, then a central cavity with the water pipes within it. At *e e* two of these water pipes are shown originating in the internal parenchyma.

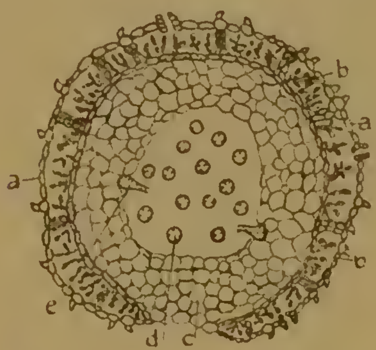

FIG. 23.—MARCHANTIA POLYMORPHA; vertical section through a finger of a female disc; *a a*, epidermis of surface embracing the whole finger except a small space; *b b*, chlorophyllous cells below the epidermis; *c*, parenchyma; *d*, water tubes in canal; *e*, water tubes originating in parenchyma on the surface of the canal. (*Magnified 50 diameters.*)

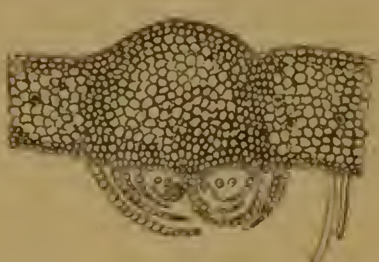

FIG. 24.—MARCHANTIA POLYMORPHA; section through angle of stalk of archegoniophore, where the scales of the ventral surface are beginning to form the canals of the stalk; *cf.* Figs. 14 and 22.

Fig. 24 shows us the base of the archegoniophore where it leaves the expanded thallus (line *b b* in Fig. 20), and we see the scales of its under surface beginning to form the two canals of the stalk. Note that just at the bend the chlorophyllous layer is absent.

Turning now to the antheridiophore, we see in Fig. 19 another modification of the thallus. Beginning on the upper surface, and descending we have first the epidermis with its stomata, and then a large development of chlorophyllous cells, then a mass of parenchyma in the body of which are contained the sack-like antherids opening by tubes on the upper surface, then the water tubes again, originating on the under surface, and protected by scales, and not as in the archegoniophore running through the body of the tissue.

If after these explanations any of my readers

feel it difficult to conceive of the whole structure as part of the thallus, I will invite him to cut out of a flat sheet of paper a figure, as shown in Fig. 25, and then to turn the paper at right angles at the points *b* and *c*, and he will have a pretty exact model of Marchantia, and will see the different positions occupied respectively by the upper and under surfaces of the thallus.

FIG. 25.—CUTTING IN PAPER to illustrate growth of MARCHANTIA POLYMORPHA. The thallus, *a*, is to remain flat; the stalk to be turned upwards at right angles at *b*, and the disc to be turned parallel with the thallus at *c*.

A comparison of the drawings already given will, I think, impress my reader with the wonderful extent to which the thallus is modified in different parts of the plant, so that the same elements are made to create very different structures.

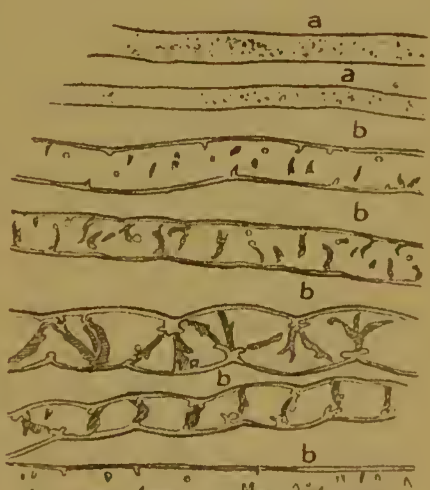

FIG. 26.—MARCHANTIA POLYMORPHA. Rootlets: *a a*, ordinary rootlets; *b b*, trabecular rhizoids of different degrees of complexity. (*Magnified 270 diameters.*)

What I have already said will show my reader that the Marchantia has a very elaborate system of water tubes. These tubes differ from the rootlets, amongst which their earthward ends are found in being marked by little notches or bars, sometimes of great complexity (Fig. 26); whereas, the rootlets are simple

long cells. These tubes, no doubt, conduct the water in two ways—first, by absorbing it and conveying it through the protoplasm of the cells, and secondly, by acting as capillaries, and so conveying the water along the outside of the tubes. Fig. 20 will give a general notion of that system of water supply. The right-hand part of the thallus (*c*) is in its natural position and shows some of the tubes escaping into the damp soil; the left-hand part of the thallus (*a*) is turned over to show the underside, and the distribution of the water-tubes to supply all the parts of the thallus, whilst the stalk of the archegoniophore shows the water tubes passing downwards from the fingers of the disc.

If we compare Marchantia and its stalked organs with *Pellia epiphylla* and its stalked organs, we shall see how different they in reality are, though so like in appearance. The stalks of Marchantia are part of the thallus; those of Pellia arise from the fertilized ovum. The stalks of Marchantia are thus part of the oophytic generation; those of Pellia belong to the sporophytic generation. The stalks of Marchantia carry on high the archegones and the antherids, whilst in the Pellia these organs remain sunk in the horizontal thallus. In Pellia the spore-case is borne upward from the thallus; in Marchantia it is formed in the fertilized archegone itself. In Marchantia the fertilized archegone becomes itself the spore-case; in Pellia the two organs are separate. In Pellia the stalk is of pellucid cells and rapid growth; in Marchantia it is of a complex thalloid character and slow growth. In both cases it will be observed that the spores are elevated above the soil, on which the plant grows, and so have a probability of a wider dispersion than if they started on the ground.

Lunularia.—Lunularia cruciata is another member of this family of the Marchanticæ which is very common in moist places and in the pots in our greenhouses; its distribution has suggested that it is an imported and not a truly native plant. The sexes are divided, and it is not uncommon, at any rate in some parts of the country, to see on the thallus of the male and female plants respectively the small wart-like elevations which are formed by the

antherids and archegones. But for some reason or the other, perhaps because the fertilization can only take place under peculiar conditions of moisture, it is extremely rare to find the spore-case.

Figs. 27 and 28 show respectively the male and female

FIG. 27.—LUNULARIA CRUCIATA; upper surface of thallus showing *a*, the young archegoniophore in a depression of the surface (*magnified*).

forms of Lunularia. Fig. 29 shows a section of the young unfertilized archegoniophore.

The spore-case of Lunularia, instead of opening by an indefinite rupture, as in the Marchantia, opens by four

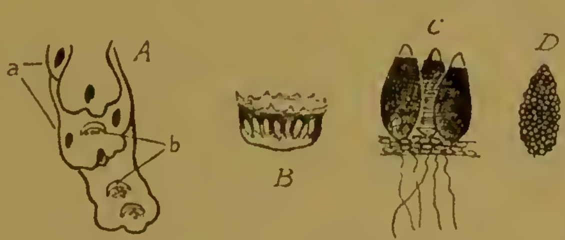

FIG. 28.—LUNULARIA CRUCIATA, male plant; *A*, thallus, with *a a*, receptacles of antherids and *b b*, receptacles of gemmæ (*about natural size*); *B*, receptacle of antherids; *C*, group of antherids enclosed in purple flasks; *D*, free antherid (*B and C magnified*).

definite valves, thus approaching the Jungermanniceæ in the method in which the sporangia open.

Lunularia is very common in its barren condition, in which, as already mentioned, it is easily distinguished from Marchantia by the form of the receptacles in which the

gemmæ are produced, for whilst these receptacles in the Marchantia are cups of a complete circular shape, in Lunularia they are crescent shaped only.

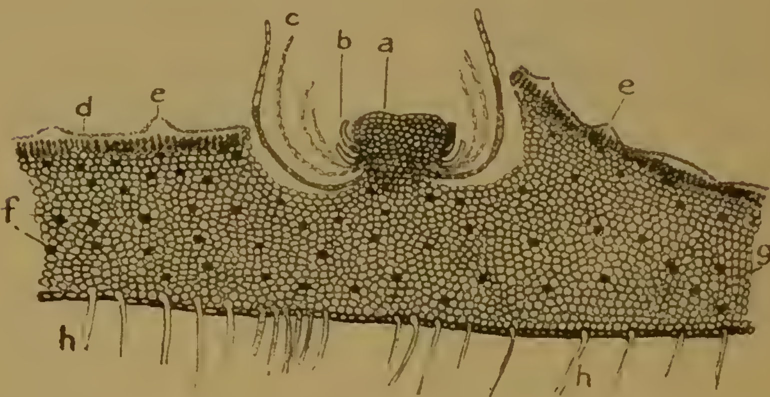

FIG. 29.—LUNULARIA CRUCIATA ; vertical section of thallus, showing *a*, young archegoniophore before fertilization ; *b*, archegone ; *c*, scales at base ; *d*, epidermis ; *e e*, stomata ; *f f*, amygdaloid bodies ; *g*, parenchyma ; *h h*, rootlets (*magnified* 26 *diameters*).

VI. Jungermannieæ.

Jungermann was a German botanist, who, in the early half of the seventeenth century, published local floras of Altorf and Giessen, and has been commemorated by the imposition of his name upon the largest group of Liverworts to which we must now give our attention. This family is characterized by the form of its spore-case, which is always carried on a stalk and opens generally with four distinct leaves, or, as they are called by some of the older botanists, petals. The spore-case is always furnished with elaters. Under a great variety of detail, this form of spore-case is maintained throughout. The group is characterized as a whole by the great diversity of forms which it contains, and by the great simplicity of its tissues, even in genera where the general appearance approaches that of the higher forms of vegetation.

Whilst the whole group is thus at one as regards the spore-cases, as regards the vegetative organs it falls into two well-marked divisions, the frondose and the foliose Jungermanniœ. The frondose are thalloid plants, in that respect like the Marchantia and the other groups with which we have dealt.

In the foliose species we find a direct step towards a vertical growth. It is true that many fungi grow upwards, such as the mushrooms and other Agarics, and it is true that the fruticose Lichens also aspire upwards. It is true also that some water cryptogams, like the Characeæ, and some of the sea-weeds assume a vertical direction in their growth. But in the Jungermannieæ we first find that upward growth combined with leaves which characterizes all the higher forms of vegetable growth.

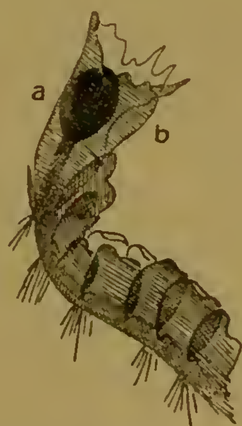

FIG. 30. — LOPHOCOLEA HETEROPHYLLA ; *a*, young capsule surrounded by *b*, perichætial bracts. (*Magnified about 5 diameters.*)

Some of these leafy Jungermannieæ cleave more or less to the soil and are provided with rootlets growing from the under side of the stem, which attach them to the ground ; these rootlets sometimes grow all along the stem, sometimes are gathered together in tufts, and sometimes proceed only from the lower part of the stem, and the free ends of the stems then lift themselves a little above the ground. Fig. 30, a drawing of *Lophocolea heterophylla*, will illustrate this form of growth. Other members of the family assume the erect posture as their ordinary mode of growing, and this change is accompanied by a change in the roots of the plant. These are no longer mere rootlets disposed along a creeping stem, but more complicated roots in which the stem terminates, much after the fashion of a flowering

plant. In the beautiful *Trichocolea tomentilla* these roots are very simple and short, whilst in *Plagiochila asplenioides*, *Adelanthus decipiens*, *Mniopsis Hookeri* there is a main root nearly of the size and structure of the stem giving out side rootlets.

Considering the great part in the furniture and adornment of this world of ours taken by trees and other plants that are endowed with a clothing of leaves of varied forms and kinds, and, secondly, with an aspiration upwards, it is interesting to enquire where first in the ascending scale of vegetable organization we meet with these characters. We find the answer in the fact that within the boundaries of both of the small group of the Monocleæ and of the large group of the Jungermannieæ a transition takes place from the earth-loving thallus to the air-loving leaves, and from the horizontal to the vertical direction of the principal growth.

The change from a thalloid to a leafy and axial growth is well worth pondering. The thalloid form is the one which would seem to present the least physical difficulty, for here the lines and planes of growth are at right angles to the force of gravity, whereas, in the case of erect plants, the line of growth is in direct opposition to the force of gravity. The enormous development of trees, the vast volumes of water which they lift from the earth to great heights, all in direct opposition to the attraction of the centre of the earth are very striking facts ; and it is curious to watch in many cases what seems the fixed determination of the plant to defy gravity. If the trunk of an apple tree fall or be bent over, it forthwith abandons the development of its former extremities, as these are now more or less parallel with the surface of the earth, and sends out fresh shoots in a vertical direction. The branches of young fir trees are originally horizontal, but as the tree advances in age its lateral branches turn upwards and their lines of growth are parallel, not with the surface of the earth, but with the trunk of the tree.

This negative geotropism of plants, as the struggle against gravity is somewhat pedantically called, suggests at first to the mind the existence of some special vital force which

acts against gravity; but we now know that no such force exists, and that whilst Life directs forces it contributes none, and thus the wonderful action against gravity to which I have referred is the result of other natural physical forces, which are directed to this result by Life, and not created anew by it.

If the thalloid form of vegetation had remained dominant, it is obvious that the world would have furnished far less room for plants than it does to-day under the domination of a leafy and axial form, for a thallus is like a house built all on a ground floor, whereas a tree is a structure of innumerable floors—a veritable sky-scraper.

When we leave the thallose for the foliose Jungermanniceæ, we part company with the thallus as the chief feature of the vegetative growth; but we have not left it entirely behind us, as we travel upwards in the Vegetable Kingdom. It reappears as the protonema of the Peat Mosses when they grow on damp soil, and not in the water; it is found again as the prothallus of the Ferns and other vascular cryptogams, and, curiously enough, it reappears in one family of flowering plants, the Podostomaceæ, a puzzling group of somewhat obscure affinities. They inhabit streams, chiefly in the tropics (I have seen one species growing in the Nile, just below what used to be the first cataract), and often their roots and shoots are fused together into a thallus, so that the whole plants are sometimes described as having the habit of the Liverworts, Would it be fanciful to compare the flat floating leaf of the Duckweed to a thallus?

Though the two groups of thallose and foliose Liverworts are broadly distinguished from one another, yet there are certain intermediate forms which serve as stepping stones over the division between them. This is an instance of a fact very common in Nature and very embarrassing to the systematist, of groups apparently very distinct, merging into one another by such intermediate forms as make it almost, if not quite impossible, to find a satisfactory differentia between them, and to render the grouping inaccurate and to a certain extent misleading.

Blasia has a form which places it at first sight distinctly

amongst the thallose group; but the margin of the frond is cut into deep and obtuse lobes of various sizes (Fig. 31). The divisions between the lobes, however, never reach so far down as the nerve, but Leitgeb considers that these lobes, by their lateral and alternative position and by their mode of origin and development, prove themselves to be true, but very simple leaves; if this be the correct view, we seem to have here the co-existence of leaves and a thalloid frond. Is the

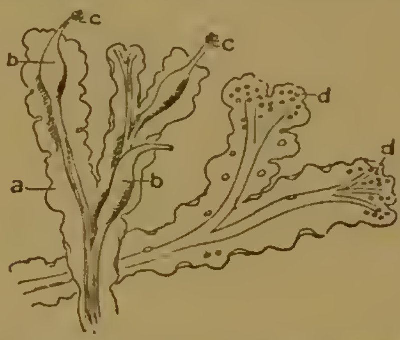

FIG. 31.—BLASIA PUSILLA. After Sir Wm. J. Hooker. *a*, thallus segmented into lobes; *b*, flask-shaped receptacles of gemmæ; *c*, gemmæ collected at the mouths of the flasks; *d d*, scattered gemma on the thallus (*magnified*).

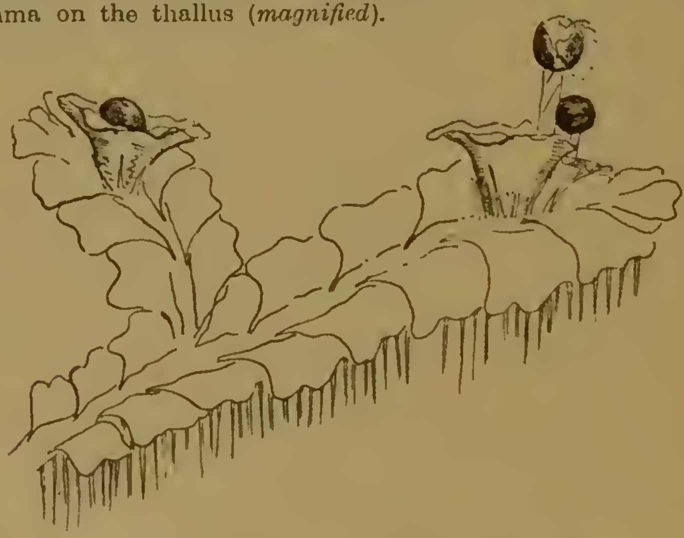

FIG. 32.—FOSSOMBRONIA PUSILLA, after Sir Wm. J. Hooker (*magnified*).

little inconspicuous Blasia the first and humblest vegetable that has clothed itself in leaves? If so, it is worthy of a great place in the thoughts of the botanist. What a

great invention for such a mean little plant to make! But Blasia is perhaps not secure of the honour of being the first to bear rudimentary leaves, for *Fossombronia pusilla* (Fig. 32) and also some species of a non-European genus *Symphyogyna* have the thallus segmented almost or quite down to the midrib, and thus reduced to a series of leaf-like divisions; furthermore, there are certain species of the genera *Blyttia*, *Hymenophytum*, *Symphyogyna* and *Aneura*, which, starting with a narrow strip of thallus, expand into leaf-like divisions, which recall the leaves of the Hymenophyllum amongst Ferns, and thus present a differentiation into parts resembling stalk and leaves. We have thus three steps towards leaves: (1) In the presence of foliar appendages on the sides of the thallus (2); in the segmentation of the thallus, and (3) in the division of the thallus into quasi stem and leaf. It should be added that, as we have seen, many

FIG. 33.—LOPHOCOLEA CUSPIDATA; *a*, cuspidate leaves; *b b*, stipules or amphigastra. (*Magnified about 8 diameters.*)

FIG. 34.—JUNGERMANNIA QUADRIPARTITA: leaves. After Sir Wm. J. Hooker. *Musci exotici* (*magnified*).

of the thallose Liverworts have scales on the under side of the thallus, and some botanists have come to regard these as rudimentary leaves. These would probably claim priority over Blasia.

Leaves.—The leaves of the foliose Jungermannieæ are remarkable in this respect, that their insertion on the stem is never at right angles to the line of the stem, but almost always at an acute angle to that line (see Fig. 33).

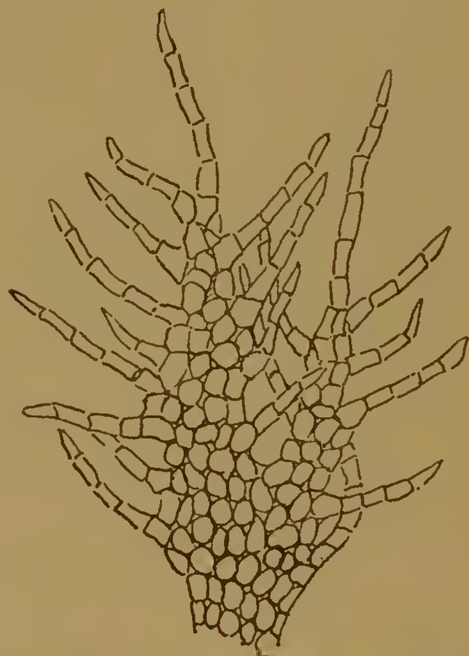

FIG. 35.—PTILIDIUM CILIARE ; leaf. (*Magnified* 109 *diameters.*)

Perhaps we have here an indication of their origin from a flat thallus, their angular insertions being intermediate between the plane of the thallus and an insertion at right angles to the stem.

No simpler form of leaf can perhaps be imagined than that of *Jungermannia quadripartita*, a species from the neighbourhood of Cape Horn. As shown in Fig. 34, the leaf consists of a single layer of cells in the form of a hand

with four tapering fingers and very little palm, and the fingers are constituted throughout nearly their whole length of a single row of cells. *Ptilidium ciliare*, a British plant, has a leaf on the same style, but with many fingers and a wider palm (Fig. 35), whilst another beautiful British species, *Tricholea tomentilla* (Fig. 36) has leaves all constructed of simple hairs, consisting of single elongated cells joined together by their short ends — a structure closely resembling that of a jointed Alga. These hairs appear to have no fixed form or number, and the whole structure hardly comes within the ordinary definition of a leaf.

FIG. 36.—TRICHOLEA TOMENTILLA; stem and leaves. (*Magnified* 33 *times.*)

Fig. 37 shows magnified the leaves of two species;

FIG. 37.—*A*, LOPHOCOLEA CUSPIDATA; *B*, KANTIA TRICHOMANIS; leaves. (*Magnified* 25 *diameters.*)

the first the *Lophocolea cuspidata* and the latter of *Kantia trichomanis*. In each case the leaf, it will be

observed, consists of a single layer of large cells, without epidermis or nerve, or border, or stoma or hair. In the case of the first leaf it will further be observed to end in two cusps or points, each terminated by a single triangular-shaped cell. I confess that the contemplation of such a leaf under the microscope has often filled me with wonder (though I know that in fact it is no more wonderful than any other leaf); I wonder to see how without fibre or thread or nerve to guide them,

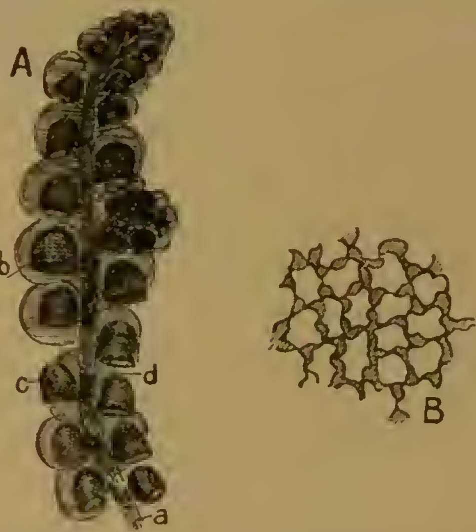

FIG. 38.—FRULLANIA DILATATA; *A, magnified* 15 *diameters,* showing *a,* the stem; *b,* larger lobe of leaf; *c,* smaller lobe of leaf; *d,* stipules or amphigastra; *B,* cells of leaf (*magnified* 225 *diameters*).

the constituent cells keep to their set and appropriate boundaries; how they multiply so as to form the leaf, but no further; how they gradually diminish in number so as to form the cusp and finally the point of the cusp. Each little cell seems to know its part in the body politic and with that knowledge to be a law unto itself and to perform its part with precision and faithfulness.

The species of the genus Frullania present a very remarkable form of leaf. *Frullania dilatata* is very common

on the trunks of trees, and *F. tamarisci* is common on rocks and also on trees; the genus is distinguished by the dark copper colour of the whole plant.

Fig. 38 presents a magnified view of a bit of stem of the former species. The leaves are divided into two very unequal lobes, and the smaller lobe is folded on the under surface of the principal lobe, and is converted into a kind

FIG. 39.—SPHENOBOLUS EXSECTÆFORMIS; stem and leaves (*magnified 55 diameters*); *a*, gemmæ.

of hood or inverted pitcher. It has been suggested with great probability that these little vessels retain moisture against the day of drought. In some forms these pitchers are inhabited by rotifers, and it has been thought that the excreta or the dead bodies of these little creatures supply the plant with highly nitrogenous food, and that they thus repay the hospitality which they receive by what must be considered as a very moderate rent.

The genus Polyotus, of which species are found in Australasia and America but not in Europe, derives its

name from the abundant growth on it of small auricles, or pitchers, very like those of Frullania, which probably serve the same purpose of storing moisture for the supply of the plant.

Other cases of folded leaves occur in this family, as in *Diplophyllum albicans* (Fig. 4), or again in the *Sphenobolus exsectæformis* (Fig. 39). The outline and attitude of this leaf may be compared to those of a hand with the thumb partially folded over on the palm, so as to leave a deep notch between the thumb and the fingers; no line could divide the leaf into two corresponding sections.

A very interesting form of perfoliate leaf is found in *Chiloscyphus coalitus* from New Zealand. Fig. 40 shows

FIG. 40.—CHILOSCYPHUS COALITUS; leaf and stem (*magnified*). After Sir Wm. J. Hooker. *Musci exotici*.

this leaf, and it is the only case, so far as my knowledge goes, of a perfoliate leaf in the whole group.

In *Sphenobolus minutus* we have another form of leaf (see Fig. 41). Take a rectangular strip of paper, bend it into the form of a half cylinder, let one end embrace a stalk in such manner that the bent paper is at an angle to the stalk, and you have the form and position of one of the leaves of this species.

Occasionally the leaves are dimorphic, that is to say the leaves on one and the same plant assume different forms. *Bassania trilobata* (Fig. 42) is a delicate little plant, growing sometimes nearly on the ground, at other times climbing up amongst beds of moss. Here and there along the back of its stem it throws out at right angles long shoots,

FIG. 41.—SPHENOBOLUS MINUTUS ; stem and leaves (*magnified* 50 *diameters*).

whip-like in appearance. These shoots are furnished not only with leaves, but towards their extremities with long root-like hairs, and they twist in and out of the Moss amongst which the plant grows, and seem to lend support to the principal stem. The leaves on the principal stem are oblong and ovate and end in three and sometimes four

blunt lobes, whence the specific name trilobata, whilst the whip-like shoots bear only minute leaves, little more than scales.

Still more various in point of form are the leaves of the little species *Haplomitrium Hookeri*. The leaves inserted, says Sir William J. Hooker, without order on every side of

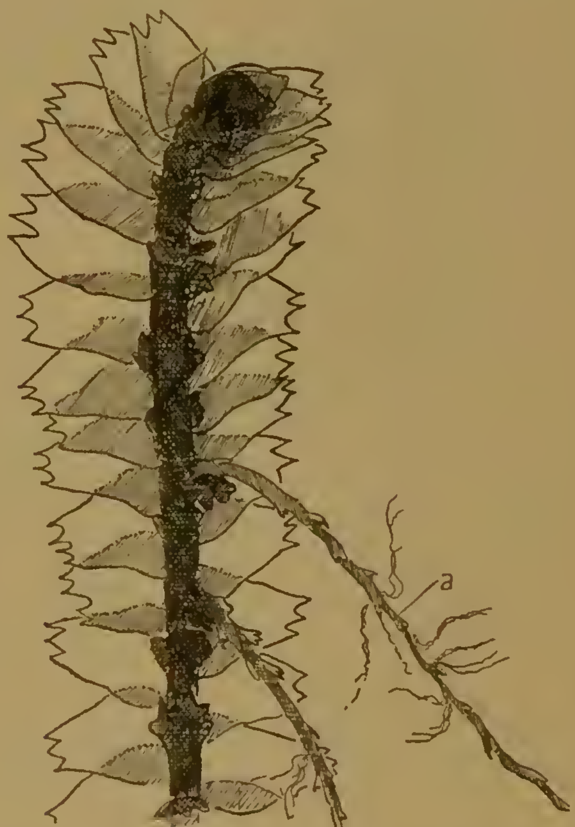

FIG. 42.—BASSANIA TRILOBATA, showing *a*, shoots with minute leaves and rootlets. (*Magnified about 7 diameters*).

the stem (in three rows, says Boulay) vary throughout the stem in size and figure; sometimes they are rounded in shape, sometimes oval or oblongo-ovate, sometimes

ligulate, plain or cut at the margin in an irregular manner. It seems almost as if the plant had never made up its mind as to what kind of leaf it will produce.

In addition to the leaves already described, many species of this family are furnished with stipules, or, as they are often called, amphigastra; these are arranged sometimes on the fruit-bearing branch of the plant—more often along the leafy stem, and then always along the under surface, whether the leaves be superior or inferior to the stem; and generally one stipule is to be found between each pair of leaves. They will be seen on Figs. 33 and 38. These stipules vary greatly in form; sometimes they are ovate, sometimes entire, sometimes toothed, sometimes ligulate, sometimes subulate. It has been observed that there is a balancing between these stipules and the ventral lobes of the leaves—that is to say, where two lobed leaves have the inferior lobe well-developed, the amphigastra are small, and when the inferior lobe is small the amphigastra are well developed.

It follows from the structure of the leaf of the Jungermannicæ that it is highly responsive to variations in the moisture of the atmosphere. No doubt each cell of a leaf in a moist situation absorbs moisture and maintains its natural size; but with drought the moisture finds its way through the thin cell wall and the cells shrink and the whole plant looks dead. Many also of the thalloid forms of Liverworts are capable of drying up with drought and reviving with the return of moisture. Every one who has worked at Liverworts or Mosses knows how completely they change their form with drought and how easily they absorb water and return to some extent to their original form.

The leaves of Jungermanniceæ are rarely symmetrical; they are never supported by a footstalk, that is to say they are always sessile, and are not even contracted at the base. In many cases the insertion of the leaf on the stalk of the plant is peculiar, being obliquely semi-amplexicaul, *i.e.*, the base of the leaf is attached to the stalk in an oblique line, extending half round the stalk (see Fig. 33). Occasionally they embrace half the stalk transversely, and at

least in one species the base of the leaf runs parallel with the stem. A remarkable exception to the ordinary position of leaves in this family is found in two genera, chiefly of foreign species, which have been classed together in a family of the Haplomitrieæ, where the leaves are radially arranged.

Very often the leaves are arranged in two rows; sometimes in four rows, and sometimes, though rarely, they arise at irregular points on the stem; often the leaves are closely packed together, often imbricated, *i.e.*, lap over one another like tiles, and so conceal sometimes the upper and sometimes the under surface of the stem. In

FIG. 43.—SCAPANIA NEMOROSA; head of male plant; *a*, antherids growing on stalks from the axils of the leaves (*magnified* 12 *diameters*).

the direction of the leaves, from horizontal to vertical or nearly vertical, great diversity exists not only in different species, but often in different parts of the same plant.

Of the form of the leaves I have already given many illustrations; but these must not for one moment be regarded as exhaustive—for in point of fact the forms are extremely various, though always characterized by a broad base of attachment to the stem. Some leaves are orbicular, others ovate, others ligulate; many, as already said, are divided into two segments, generally of unequal size. In most cases the margins of the leaves are entire; but sometimes they are serrate or dentate, or ciliate (Fig. 43).

If we compare the leaf of a Jungermannia with those of the Mosses, we shall find in the latter not inconsiderable advance in complexity of structure. In the case of many of the Mosses, a considerable difference of form exists between the cells at the base and in the middle and extremity of the leaf; in others the cells of the mesial line of the leaf, and often of the border of the leaf are lengthened and form respectively a nerve or midrib, and a border, and that border is sometimes equipped with teeth: often the end of the leaf is prolonged into a spine or hair—sometimes the leaf is bistratose, *i.e.*, composed of two contiguous layers of cells—and in the genus Polytrichum a section of the leaf exhibits the differentiation into an upper and lower epidermis and a parenchymatous interior of the leaf.

In the Liverworts, on the contrary, the leaf is never, I believe, surrounded by cells specialized so as to form an edge or border, and it is only in one or two species that a mesial line is marked by cells so as to form at all the semblance of a midrib. *Diplophyllum albicans* (Fig. 4) and some species of Scapania may be cited as showing such forms. It is evident, therefore, that the true Mosses have advanced on the Liverworts in the structure of the leaf.

According to the received doctrine of the alternation of generations, the leaves of the Liverworts and of the Mosses are the only ones in the world which belong to the oophytic generation, whilst the fronds of Ferns and the leaves of Phanerogams belong to the sporophytic generation and, if so, there can be no genetic relationship between the leaves of Mosses and of flowering plants. It may nevertheless be permitted to compare them. In the leaves of the more highly organized plants we find a complexity of structure strikingly in contrast with the simple cellular plates of the Jungermannieæ. A section of a phanerogamous leaf will exhibit to us, proceeding from above downwards, first an epidermis constituted of a single layer of special cells, then a layer of larger cells, known as the pallisade cells from their arrangement, then the parenchyma, traversed by spiral vessels, and then the epidermis of the inferior surface of the leaf, furnished with stomata or breathing-mouths, protected by guard cells. The leaf, moreover,

is generally provided with a footstalk, with a central vascular midrib which with smaller vascular bundles proceeding from it in all directions form the skeleton of the leaf. The comparison of the two leaves exhibits to us forcibly that common contrast between a simple organism, where every part can do everything, and a complex organism, where each part can do only something and never everything.

Perhaps I owe my reader an apology for the length at which I have dwelt upon the form and characters of the leaves of the Jungermannieæ. My apology must be that I have been led on by the variety and beauty of their forms and by the admiration aroused by the skill of Nature in devising such a profusion of lovely things to serve one and the same purpose, and all wrought out of a few simple elements. Truly, as Aristotle said, in the words cited on my title page, there dwells in all natural things something of the marvellous.

Reproduction.—The reproductive organs of the Jungermannieæ consist of an archegone and antherids. In the foliose group the archegone is a cell usually formed at the end of the axis of growth or of a lateral or root branch, and is surrounded by special leaves; whilst in the thalloid group the archegones are to be found on the upper or under surface of the thallus—usually on the upper and at some distance from the apex. Antherids in the foliose group usually spring from the principal stalk at the axils of the leaves, and are often accompanied by elongated cells known as paraphyses. The antherizoids are similar in form and behaviour to those of the Marchantia. In all cases it would appear that water is thus essential to the fertilization of the plant. The fertilized archegone throws up a stalk, usually consisting of white colourless cells, on the end of which is formed the spore-case; this, when maturity is reached, opens into four leaves, which turn downward and throw out the spores. Fig. 44 shows in the case of *Frullania dilatata*, first the perichætium (*a*) containing the fertilized ovum, then outside of this the modified leaves known as the perichætial leaves (*b*), and then the seta or stem (*c*), then the capsule opened

into four leaves (*d*), then the elaters (*e*), and, lastly, the object and end of this whole structure, the spores (*f*).

FIG. 44.—FRULLANIA DILATATA (*magnified* 10 *diameters*); *a*, perichætium; *b*, perichætial leaves; *c*, seta; *d*, capsule; *e*, elaters; *f*, spores.

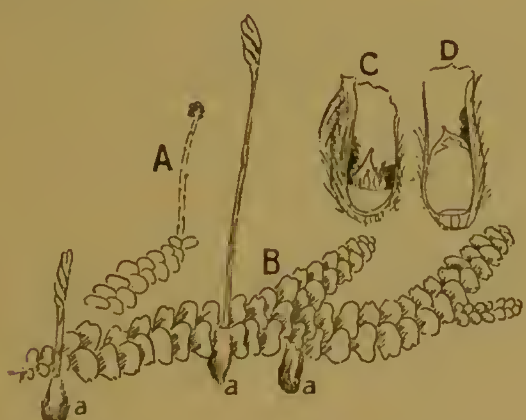

FIG. 45.—KANTIA TRICHOMANIS, after Sir Wm. J. Hooker. *A*, gemmiferous head; *B*, female plant, with *a a a*, archegonial sacks; *C*, young archegonial sack cut open; *D*, same mature.

In some few Jungermanniceæ, the female organ, instead of being formed at the end of the axis of growth, is

developed in a long sack-like organ which grows downward and which is attached to the stem by the side of the mouth. This sack is sometimes sunk in the soil, from which this group has been described as the Geocalyceæ. Examples of this very peculiar structure may be found in British species (*Kantia trichomanis* and *Saccogyna viticulosa*). (See Fig. 45.)

VII. Modes of Reproduction.

Now that we have considered, if only in a superficial way, the structures exhibited by the five tribes or families into which the Liverworts may be divided, I will proceed to consider a little more fully some points in their history.

Looking back over the whole group, we are now in a position to consider the modes of reproduction which prevail amongst them. These modes may be enumerated as follows:—

i. By spores, in the most formal and orthodox manner, the end and object, as we have seen, of the two generations, the oophytic and sporophytic.
ii. By means of gemmæ.
iii. By means of zoospores.
iv. From rhizoids.
v. From the stem or leaves.
vi. By tubers.
vii. By means of scission of part of the parent plant.

All these modes of reproduction, except by spores, arise from the oophytic generation, reproduce the same generation and avoid and elude the sporophytic generation.

Of the reproduction by spores I have already given some account in the early pages of this volume.

Gemmæ.—The gemmæ are produced on various parts of the plant. They are highly developed in Marchantia where, as already mentioned, they occupy small cups on the surface of the thallus; in Lunularia they are half enclosed in a crescent-shaped receptacle; amongst the Jungermanniceæ, as amongst the true Mosses, they arise

from various parts of the plant—sometimes from the stems, sometimes from the margin of the leaves, sometimes from the end.

The intimate structure of the gemmæ varies considerably. Some consist of single cells, some are built up of several cells; some are spherical, some ovate, some angular in shape; some green and some red. The following table, which is no doubt imperfect, will illustrate the mode and character of their production in the single family of the Jungermannieæ:—

Unicellular Gemmæ.

Plant.	Place of Production.	Form, &c.
Lophocolea sp.	All along the edge of leaves	Ovoid.
Cephalozia bicuspidata	In clusters at the end of branches, on a distinct form of the plants.	Roughly spherical.
Scapania nemorosa	In dark rufous-coloured clusters at ends of leaves at apex of stem.	
Aplozia Schraderi	Similar position	Angular.
Sphenobolus exsectæformis	In clusters at the points of some 8 or 10 terminal leaves.	Roughly spherical.
Lophozia ventricosa	Similar position	Somewhat angular.
Lophozia incisa	Similar position.	Spherical, but rough.
Anastrepta orcadensis	Similar position	Angular.
Odontoschisma sphagni	Scattered on stipules, and leaves of elongations of the plant, distinguished from the rest of the stem by their smaller size, their gradual tapering to the apex, by the diminutive leaves and by the presence of stipules, not elsewhere found.	Somewhat angular.
Kantia trichomanis	In balls, on extremities of the plant, lengthened into an almost leafless stem.	
Lophozia excisa	On ends of terminal leaves.	
Blasia pusilla	In clusters arising in the tissue of the leaf	Ovate.

MULTICELLULAR GEMMÆ.

Plant.	Place of Production.	Form, &c.
Cololejeunea calyptrifolia.	Various parts of stem..	Nearly orbicular.
Radula complanata	On margin of leaves; ordinary and perichætal.	Roundish or ovate.
Metzgeria furcata..	In clusters on the ends; on specially modified fronds with recurved margin.	Roundish or ovate.
Drepanolejeunea hamatifolia ..	On stem.	
Lejeunea cavefolia	On stem.	
Cololejeunea minutissima ..	On stem.	
Blasia pusilla	In bottle-shaped receptacles on the nerve.	Spherical.
Lophozia excisa	On ends of the top leaves, in clusters ..	Irregular, conical, on slender stalks.

The consideration of this table may give rise to several reflections. In the first place the facts show, as similar facts in the Mosses show, either that there is no division of plasma into germ plasma and somatic plasma, as Weissman has contended, or that the former is very widely distributed throughout these plants.

Then we observe that in some cases the production of gemmæ is co-ordinated with a change in the general mode of growth of the plants, as in *Metzgeria furcata*, *Odontoschisma sphagni*, or *Kantia trichomanis*. This again is analogous with what we know in some Mosses, *e.g.*, in *Aulocomnium palustre*, where the general appearance of the gemmiparous and spore-bearing plants is widely different.

FIG. 46.—BLASIA PUSILLA, after Sir Wm. J. Hooker. *a*, flask-shaped receptacle of gemmæ opened; *b*, group of gemmæ collected at end of the tube of the receptacle; *c c*, gemmæ (*more highly magnified*).

Again, it will be observed that *Blasia pusilla* appears in both parts of my table, for it produces gemmæ of two forms and in two different manners, and so seems to deserve special mention. The first kind are gemmæ consisting of several cells of unequal size, and furnished with a short tail or attachment; these appear to be very similar to the gemmæ of Marchantia. They are produced in flask-shaped receptacles, which grow in the spring and summer on the nerve of the plant and towards the extremity of the thallus. Fig. 31 shows both forms of gemmæ; *b b* are receptacles on the nerve; *d d*, scattered gemmæ on the thallus. Fig. 46 is a magnified representation of a section of one of the flask-like receptacles, and shows the open tube through which the gemmæ escape from the flask. Sometimes these

gemmæ collect round the mouth of the tube and form a sort of head or bunch, recalling like growth in some of the Mosses, *e.g.*, Aulocomnium. There can, I think, be no doubt that these gemmæ are reproductive.

The other gemmæ of Blasia consist of single cells of a darkish colour and of a spherical or ovoid form, which arise in thick masses at points in the substance of the thallus on either side of the nerve and never upon it. These groups of cells are seen as black spots on the leaf; they are nearer to the ventral than to the dorsal surface of the frond, and are covered on the ventral surface by a thin membrane. Whether these single and independent cells are reproductive I do not know. I strongly suspect that they are; if they are not, I am at a loss to suggest what function they perform.

It has been observed that when a plant is prolific in spores, the production by gemmæ is generally restricted, and that, conversely, when the plant is barren of spores, it abounds in gemmæ. In the woody regions where there is much water, in streams or cascades, and the situations are highly favourable to Liverworts, fructification is common and gemmæ rare; whereas in more exposed situations, with greater changes of moisture, more gemmæ and fewer spores are found to be produced.

Sometimes before parting from the parent plant a gemma will undergo very considerable development and become differentiated into rootlets, an apical cell and a mass of cellular tissue ready for further differentiation.

Where plants are diœcious, as the *Marchantia polymorpha*, a question arises whether the gemmæ of a male and female plant respectively produce plants of the same sex only as the parent plant, or whether the gemmæ may produce indifferently plants of either kind. Observations on the gemmæ of *Marchantia polymorpha* tend to show that like produces like in the matter of sex; but more extensive observations seem to be required to throw light on the subject. It is evidently one of some interest, as it tends to show at what stage and to what extent the sexual differentiation occurs.

Zoospores.—Reproduction by zoosphores has as yet,

I believe, been observed only in one case, that of the *Ancura multifida*, but as it is an event very likely to escape observation, it may well be that it occurs in other cases; and the fact is one of great interest, as showing a relation with the green Algæ. In a great many of the families of the Algæ non-sexual reproduction occurs by means of minute masses of protoplasm formed within a cell of the parent and emitted from the cell, and generally furnished with two or more cilia. These bodies are known as zoospores. In like manner in the Aneura it has been found that masses of protoplasm are expelled from cells of the thallus, that they then undergo division so as to form two-celled bodies which ultimately produce the young plant. The zoospores of the Aneura are not provided with cilia, a fact which has been attributed to the terrestrial habit of the plant, as the function of the cilia is to produce motion in water.

FIG. 47. — PLAGIOCHILA ASPLENIOIDES; leaf throwing out from its base rootlets which are developing into young plants (*magnified* 60 *diameters*).

Rhizoids and Shoots.—In many of the Ricciœ the ventral surface of the midrib gives off adventitious shoots, which become detached and form new individuals. The manner of growth is probably the same as from a germinating spore. In one of our common Mosses, *Grimmia pulvinata,* in like manner young plants are developed from the rhizoids. Very similar to this is the case I have seen of the growth of rootlets from the base of the leaf in *Plagiochila asplenioides.* From Fig. 47 it will be seen that the leaf sends off from its base simple rootlets, throwing out lateral cells; apparently we have here the origins of two new plants.

In *Radula complanata* rootlets grow down from the fold between the larger and smaller lobes of the leaf, and no doubt develop into young plants.

Young Plants from Stems.—Furthermore, cases have been observed in which young plants have arisen directly from almost any part of the stem or leaves of the old plant, which reminds one of the growth of young plants of Sphagnum from the ends of the branches of an old plant, and is the most simple and direct mode of reproduction imaginable.

Tubers.—In some species of Anthoceros, Fossombronia and other genera, reproduction has been found to take place by means of tubers. In Anthoceros these tubers are formed by way of outgrowth from the thallus, arising from its thickened mid-rib-like portion ; they have long stalks from the thallus, they develop rhizoids and then become detached from the parent stock by the death of the stalk and ultimately give rise to new plants.

Scission.—Another mode of reproduction may be illustrated by two common English species of thallose Jungermanniеæ. In *Pellia epiphylla* (Fig. 2), the broad thallus often throws off from its extremity an innovation, much narrower than the parent frond, and at first of a lighter colour ; this throws its rootlets downwards, the older fronds decay and the innovation then becomes a new and separate plant. In *Metzgeria furcata*, a distinct midrib of thickened cells runs down the fronds of the thallus which gives rise to innovations beginning as ovate shoots, which, develop into plants like the parent, strike their roots downwards, separate from the original shoot, and then become new and independent plants. This mode of reproduction closely resembles that of some Mosses, as Conomitrium, when a leafy branch becomes detached and grows into a new individual.

These cases are very interesting as illustrative of the relation between ordinary growth and reproduction.

This great diversity of the methods of reproduction and the great variety of the parts of this plant which may give rise to progeny will, I think, make one ready to accept the view of Professor Goebel when he says " I have been led by

my investigations to the view that every cell in the Hepaticæ has the latent capacity to develop further like the spore."

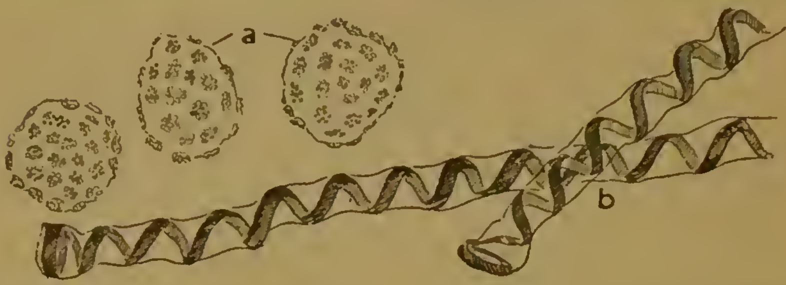

FIG. 48.—FRULLANIA DILATATA; *a*, spores; *b*, elaters (*magnified 270 diameters*).

VIII. Elaters, Odour and Water Supply.

We have already seen that the spore-cases of nearly all the Liverworts are furnished with elaters, but a few more words may well be said about them.

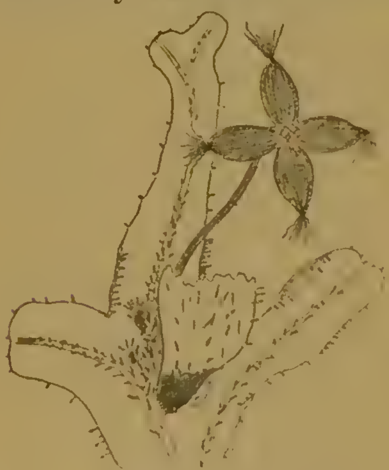

FIG. 49.—METZGERIA FURCATA (*magnified about* 9 *diameters*): elaters are seen on the ends of the valves.

Fig. 48 represents an elater of *Frullania dilatata.* It will be seen to be a hollow tube, terminating in a blunt end, the membrane of which is supported by a spiral line of thickening. When the spore-case ripens, its contents are differentiated into spores and elaters, which are thus distributed amongst the spores, and, when the spore-case springs open, by a twisting motion, probably aid in the distribution of the spores. These little threads are sometimes free; at other times they are attached at one end to the walls of the spore-case; in *Metzgeria furcata* (Fig. 49) and some other species they are gathered together in a tuft.

Elaters very similar to those of the Liverworts are characteristic of the remarkable family of the Mycetozoa, and the differences in the forms of these hairs are often valuable to the systematist as generic or specific characters. In the true Mosses and the Peat Mosses elaters are never found, but, as we have seen, are present in all Liverworts except the Ricciæ, and thus their presence forms a point of distinction between nearly all the Liverworts and their kindred groups.

We seem able to trace the development of these organs in the group of the Anthocereæ. In the genus Notothylas the cells which are not converted into spores are marked with curved, thickened bands and separate into irregular groups; they are the rejected matter not required for the office of reproduction, and appear to be of little functional value. In the genus Anthoceros this waste material assumes the form of lengthened cells, but without spiral markings, whilst in the third genera Dendroceros these lengthened cells are marked with spiral bands and have assumed the form of half developed elaters. It would seem as if Nature, like a careful manufacturer, gradually made a more and more definite use of the waste products of her operations.

Odour.—Many of the Liverworts have a strong smell, both when fresh and when dried. In the tissue of many species are found globules of highly scented oil, to which the odour of the plants is no doubt due. This scent appears to be useful to these plants, as it has been observed that they are never attacked by insects or worms, and that even in the herbarium they are not attacked by injurious insects until by a slow evaporation the oil has disappeared.

Water Supply.—If I were to speak of Nature "after the manner of men" I should say that there is nothing about which she is more anxious than the due supply of moisture to each subject of her vegetable kingdom. In the higher vegetables every one knows that there are elaborate schemes for the conduct and storage of water; and in the group with which we are now concerned the same is to be found; nor is this wonderful when we recollect that in all but the higher plants the male cell has

to swim to the female cell, and therefore without a due supply of moisture fertilization cannot occur.

I have already described the elaborate system for the supply of the vegetative and reproductive organs of Marchantia; in other Liverworts the needful moisture is stored and retained by a great variety of different methods, Nature, as it would seem, scorning to do in one way what can be done in many; in *Tricholea tomentilla* (Fig. 36) the leaves consist almost entirely of hairs and the stem is surrounded by outgrowths of hairs, so that the whole plant constitutes a sponge; and a similar result is attained in the same way in other species of that genus and of the genus Stephaniella. Many of the foliose Jungermanniceæ, as we have seen, are furnished on their under side with small leaves or stipules (amphigastra as they are called), and these are generally closely appressed to the under surface of the stalk, and thus no doubt retain moisture in the fold. In Frullania (Fig. 38), a British genus, and still more in the foreign genus Polyotus, the leaves are furnished with pitchers, which no doubt act as small cisterns for the retention of moisture. Lastly, we have seen cases (see Fig. 43) in which a smaller part of the leaf is folded over a larger part, and here again the fold will protect the water from being dried up for a certain time.

No doubt many of this family inhabit situations of permanent moisture and then so flourish as to constitute considerable masses, and no doubt also many species can endure drought for a considerable time, and revive on the return of moisture. But these facts have not relieved the kindly mother—Nature—from the care of providing a water supply to many species.

IX. Alternation of Generation.

I have already referred more than once to the theory or the set of facts known as the alternation of generations, according to which, what to the uneducated eye appears as a single plant of a single generation is, in reality two organisms of two separate and successive generations, differing the one

from the other in character and appearance, the one generation being produced from a spore and resulting in an ovum; the other being produced from an ovum and ending in a spore. This is held to apply not only to cryptogamous, but also to phanerogamous plants, in which the seed produces the outward and visible plant, which is regarded as one generation, whilst the prothallium hidden away in the embryo sac is regarded as the other generation.

To avoid confusion let me repeat that the generation which is produced from a spore and produces an ovum is called the oophytic or gametophytic; the generation which is produced from an ovum and produces a spore, is the sporophytic: the thing produced, and not the thing producing gives the name.

We may now consider how this alternation of generations can be traced in the various forms of Liverworts.

The Jungermannieæ seem to present two distinct habits of development; sometimes the spore develops directly into the young oophyte (or gametophyte). In other cases, including the whole of the foliose forms, the spore develops into a distinct protonema, which again presents two forms, sometimes that of a thallus, like the permanent form of some of the thalloid Liverworts, sometimes that of branching filaments, consisting of long cells placed end to end (and resembling the protonema of Mosses), which is sometimes long-lived and persistent and producing numerous tetrahedral cells which develop into young plants.

Again in Anthoceros and Monoclea we have a scheme very like that of the Mosses, and we may seek as in these to divide the whole life-history into two separate sections or generations, viz., from spore to fertilized archegone and from fertilized archegone to spore. But with the Marchantieæ and the Riccieæ the case is different and the sporogone (containing in the Marchantieæ the spores and elaters, and in the case of the Riccieæ the spore alone) is developed within the body of the fertilized archegone itself, and is never separated from it by the growth of a stem or seta. Thus, as we have seen, in Riccia the result of fertilization is a small spherical body which is in no way detached from the thallus, and it requires perhaps some

effort of the imagination to think of this small thing as consisting of two co-existent organisms and embodying two generations.

This simple organism in the Riccia has been often regarded as a primitive form, and its great simplicity seems to make such a view highly probable. If so, in the early forms of Muscineæ we must regard the oophytic generation as the predominant one, and the sphorophytic to be represented only by the spore-case and its contents: this may be the truth; but this hypothesis is met by a counter hypothesis based on another very remarkable organism, one of the true Mosses, the little Buxbaumia, a form of Moss so quaint and simple and remote from all its congeners as to suggest to some botanists that it, too, is a survival of a very early form. But one of the great peculiarities of the Buxbaumia is that in it the oophyte is almost suppressed, and the sporophyte is the dominant element in the organism. The two hypotheses cannot stand together, for the one is that in the ancestral form of the Muscineæ the sporophyte was the dominant or sole element, the other that the oophyte was this element. Speculations about ancestors are always attractive, but not always very certain.

If we regard these two forms, the Riccia and the Buxbaumia as early forms, and this seems very probable, we are led to this conclusion—that the alternative of generations is obscure, if existent, in the earlier forms, and that it has either arisen or acquired emphasis in the subsequent course of development of the organisms. The comparison of a Riccia with a Jungermannia certainly seems to favour this view.

X. Classification.

Having given some short account of the five tribes or families into which the Liverworts may be divided, we are in a position to recur to the subject of classification, and, so to speak, to justify the outline of it given on an early page.

The group of the Liverworts contains, as we have seen, members which in some respects are more highly organized

than some Mosses, but contains also some very simple forms, so that, on the whole, I think my reader will agree that the group must be considered as inferior to the true Mosses, as in fact standing between the Algæ below them and the true Mosses above them.

It will now be convenient to present in a tabular and dichotomous form a classification of the families into which we have divided the Liverworts.

The presence of a small central column in the spore-case is a common feature amongst the true Mosses. This is known as the columella. It is found amongst the Liverworts, as already mentioned, only in the rather small family of the Anthoceroæ, and therefore separates them from their congene s.

The spore-cases of nearly all the Liverworts are, as we have already seen, provided with the delicate spiral threads known as elaters. The small family of the Ricciæ is, however, an exception, and this absence of elaters enables us to separate them from their cousins.

The fact that the archegones and antherids of the Marchantieæ are carried on pedicelled discs is peculiar to this family and separates them from the rest of the Liverworts.

There remain two families—the small one of the Monocleæ and the large one of the Jungermannieæ—the one characterized by the sporangium opening lengthwise, the other by its opening normally with four valves, and in a few cases irregularly and without definite lines of scission.

As the Jungermannieæ are a large family with widely distinguished subordinate groups, it will be convenient that our table shall carry on the classification of this group a step further than in the other cases. As already shown, one part of this family has a thalloid or frondose vegetative growth; the other group is characterized by its leafy vegetation, and this latter group may be divided into sub-groups, according as the stems are or are not furnished with stipules.

These points are summed up in the following table :—

i.	Spore case with columella	Anthocereæ		
	Spore case without columella.	ii.		
ii.	Spore case without elaters.	Ricciæ.		
	Spore case with elaters.	iii.		
iii.	Archegones and antherids on pedicelled discs.	Marchantieæ.		
	Archegones and antherids not so borne.	iv.		
iv.	Spore case opening lengthwise.	Monocleæ.		
	Spore case not opening lengthwise but with four valves	Jungermannieæ	Vegetative growth thalloid	Frondosæ.
			Vegetative growth leafy.	Foliosæ; stem furnished with stipules. Stipulatæ.
				Stem not furnished with stipules. Exstipulatæ.

In the foregoing table and elsewhere I have put forward as the differentia on which the primary division of the Jungermannieæ is to be based, the answer to the question whether the plant be frondose or foliose, has a thallus or leaves. An alternative classification has been based by some recent botanists on another point of difference, viz., the question whether the female cell or archegone is or is not borne at the end of the axis or a branch. Those in which the female cell is so borne they denominate *Jungermannieæ acrogynæ*, and they are very nearly, though not precisely, co-extensive with the foliose group; those on which the female cell is not borne at the end of the axis or a branch they know as *Jungermannieæ anacrogynæ*, and they are consequently nearly, though not precisely, co-extensive with the thallose group of the older classification.

The way in which the two classifications cross one another may be illustrated by a large Liverwort from Java (*Treubia insignis*) which is described as being a large foliose plant, but not carrying its female cell at the extremity of the axis or a branch.

Again in the genus Fossombronia we have true leaves, but the archegone is not carried on the extremity of the axis or a branch. It is therefore a foliose, but anacrogynous Jungermannia. All the Acrogynæ are foliose, but some foliose are not Acrogynæ.

The series of papers by Prof. F. Cavers on "The Interrelationships of the Bryophyta" now (1910) in course of publication in the *New Phytologist* contains an elaborate and interesting discussion of the relationships and classification of the Liverworts.

The Jungermannieæ present, as we have seen, very considerable diversities of form, which merge into one another in a way which renders the detailed classification far from easy.

XI. Distribution.

In Space.—The Mosses, those near relatives of our Liverworts, have played, if not a great, yet a visible part in the world's history. They have formed the peat beds of the

swamps and moorlands; they have dried up morasses; they have destroyed forests; they have assisted in binding the sand of the seashore into coherent sandhills. It is almost certain that in some of these operations the Liverworts must have played the part of allies of their more powerful relatives; but it is difficult or impossible to assign them any distinct part in the operations to which I have referred. Here and there a patch of the British species of Frullania will lend a hue of dull purple to the trunk of some ash tree, whilst other species of the same genus are said to hang in long strands of deep colour from the trees of the South American forests. Here and there a Metzgeria will form a patch of yellowish green on some rock; but, speaking generally, the Liverworts, so far as I know them, never grow in great masses like, for instance, the Peat Mosses; they never give the tone to the landscape like some species of Racomitrium, and thus they never present themselves to the eye of the ordinary spectator to the same extent as their cousins the Mosses, amongst whom many of them grow in modest seclusion.

In 1895 nearly 4,000 species of the Hepaticæ were enumerated, and were allotted in the following way:—

The families of Marchantieæ and Riccieæ, 275 species, of which more than 100 belonged to the genus Riccia; thallose Jungermannieæ, 264 species; foliose Jungermannieæ, more than 3,300 species; Anthocereæ, 103 species.

The whole group is not a very large one as regards species, less, it has been observed, than half the number of species comprised in the single family of the Composites amongst flowering plants, and of the several families of the Hepatics, the foliose Jungermannieæ is, it will be observed, far the most remarkable for the number of its species.

The distribution of the Liverworts in space presents some very interesting facts. Some of the dominant groups and some of the individual species of these groups have a very wide distribution over the world. The smaller groups in many cases present the remarkable fact of a very wide but discontinuous distribution; in other cases they exhibit the more familiar fact of a very narrow area of habitation.

Let us take some instances. The well-known and very

common *Marchantia polymorpha* has a very wide distribution. It is found throughout the whole of Europe and North America, in Australia, Tasmania, New Zealand, and in Java, Abyssinia, the Falkland Islands, Kerguelen's Land and Cape Horn, and, as is common with widely distributed organisms, it appears under slightly different varieties in different localities. Nearly twenty different varieties and subvarieties have been observed by the diligence of botanists.

Take again our common *Lophocolea bidentata*, of which five varieties have been described. This may be found throughout the whole of Europe, in North America, in Java, in the Neilgherry Mountains of India, in the Sandwich Islands, at the Cape of Good Hope, and elsewhere.

On the other hand, the distribution of some of the rarer forms is very remarkable for its discontinuity, and at other times for the narrowness of the area. The curious family already referred to, Monocleæ, illustrates both these facts. The family may be taken to consist of two genera and two species. Of these *Calobryum Blumii* is only known as a rare inhabitant of the mountains of Java; the other, *Monoclea Forsteri*, originally known as collected by Forster on the "Insulæ australes," whatever they may be, is now known also from far off Chili and Jamaica.

Or take again the genus Dendroceros, one of the Anthocereæ; one species has been found in the island of St. Vincent; one in Jamaica and Brazil; one in St. Christopher; one in Brazil; one in the island of Bourbon; one in Java; one in St. Helena and one in New Zealand. These island habitats, widely separated by vast reaches of ocean, suggest that the species are descendants of a widely spread form; that they fared but ill in the struggle for existence and have only been able to maintain themselves in their several island fortresses.

Again the genus Targionia consisting of two species, is represented in Southern and Western Europe, Africa, Java, Australia, and Western America, whilst it is absent from Eastern America and most of Asia. *Treubia insignis* has been found as yet only on Mount Gedeh in Java and in New Zealand.

As instances of very restricted areas for single species, in addition to Calobryum, already mentioned, may be taken *Wiesnerella javanica*, as yet known only from Mount Gedeh in Java, and *Geothallus tuberosus*, only found as yet at San Diego in California.

Habitats.—Of the Liverworts it has been observed that, even more than the Mosses, they avoid the neighbourhood of man. The Marchantia, and more frequently the Lunularia, may be found by trodden ways. The Riccia may be found in ploughed fields, and a few other species have been seen near human habitations, but for the most part these little plants are genuine rustics, loving our woods, our streams and our country banks.

The greater part of the Liverworts find their favourite homes in moist and warm situations; but they are not confined to such localities. Some species as *Ricciocarpus natans* and *Ricciella fluitans* live in fresh water, some on the stems of trees, some on rocks and a few affect very dry situations. The most remarkable of the few Liverworts that love such places would seem to be the rather newly discovered (1894) *Stephaniella paraphyllina*, which grows upon a clayey soil liable to great dryness, and meets the difficulties thus presented to it by boring the earth by a long rhizome like a great tap root, covered with rhizoids, which vividly recalls the great tap roots of some small desert plants.

In Time.—Of direct evidence as to the antiquity of the Hepatics, I know only of the discovery in the Lower Carboniferous rocks of Scotland of a specimen of large dichotomus thallus with a distinct midrib resembling a large thalloid Liverwort which has been provisionally referred to a genus Marchantites, and the fact that similar specimens have been described from yet earlier rocks. Ought this paucity of fossil remains to be considered as evidence that the Hepatics did not exist when the rocks were laid down? On the one hand, their structure is so delicate, so entirely wanting in fibre or vessel or woody substance of any kind that they are obviously less likely than vascular plants to leave their impression on the rocks, and so they may well have lived in abundance and died leaving no visible

trace behind them of their placid existence. On the other hand, it is to be observed that coal contains a great variety of remains of plants of various kinds, of which the most delicate tissues are frequently preserved, and yet no trace of a Moss. or Liverwort has been detected—a fact which has been thought to suggest the conclusion that these plants if they existed in the Carboniferous age, as the Marchantites seems to show, could have played no important part.

But if the direct evidence of the existence of the Liverworts in early geological epochs is weak, there are some considerations which make us inclined to attribute to them very considerable antiquity.

In the first place it is difficult to resist the conclusion that the foliose Jungermannieæ are the descendants of the thallose forms of Liverworts, and we must allow the time demanded for such an evolution.

It is equally difficult not to believe that the true Mosses are related as descendants to the Liverworts, and therefore we must attribute to the Liverworts an origin so far before that of the oldest Mosses as to enable this evolutionary process to have occurred. The upper coal measures of Commentrey have yielded a fossil which has been named *Muscites polytrichaceus*, which is supposed to have been a Moss with affinities to the Polytrichaceæ.

Another argument in the same direction has been drawn from the distribution of Liverworts on the surface of the globe. It is suggested that the spores of many species are adapted rather to speedy growth than to the prolonged retention of vitality, that they are therefore not likely to have passed over long distances of sea, and that consequently such discontinuous distribution as I have already referred to must indicate that such plants as the Treubia, which is found as yet only in Java and New Zealand, are the little changed descendants of ancient widely distributed types.

In support of the view that the Hepatics are not highly adapted to dispersion by the ordinary methods now in action, it may be mentioned that in the quarter of a century which has elapsed since the destruction of vegetation on the Island of Krakatoa by the celebrated eruption

of 1883, 92 Phanerogamous plants, 15 Ferns, 2 Mosses have established themselves on the island, but only one single Hepatic, namely a species of Anthoceros; and that, although the neighbouring islands of Sumatra and Java are the homes of numerous species.

If we were to suppose the Bryophytes, *i.e.*, the Liverworts and Mosses, to have been the ancestors of our flowering plants, we must allow a yet longer period for that great step in the evolution of plants. But it has been often observed that a great chasm separates the Mosses from the Ferns, a chasm which has certainly not yet been bridged over by any safe track; and it may therefore well be that the vascular plants do not claim the cellular Mosses as their ancestors, that there have been two distinct lines of development in the vegetable kingdom, and that the vascular plants may be as old or even older than their cellular brethren.

It would not, I think, be easy to find many purposes to which Hepatics have been put by man. But one case can be cited in which prehistoric man made some use of them. In the spring of 1881 there was unearthed at Brigg in Lincolnshire a prehistoric boat or canoe, near one end of which a stern board had been inserted in a groove carried down the inside and along the bottom, and this had been caulked with Moss and Liverworts. The preservation of these ancient plants was very remarkable, many of the specimens showing the minute structure as well as recent specimens. The collection included eight species of Mosses and eight of Liverworts, all of which are probably British of to-day. In like manner it is probable that in many cases in which moss has been used for stuffing, some Liverworts have been unconsciously used with it.

XII. Conclusion.

Books.—It may be well before I conclude that I should suggest a few books which may be useful to a person desiring to study the Liverworts. Of course, the general works on Cryptogamic Botany, such as those of Sachs and Goebel and of Bennett and Murray, contain much

information on the structure of these plants. Of books on the special subject, I may mention Cooke's "Handbook of British Hepaticæ, 1894," which contains illustrations; "A List of British Hepatics," by the Rev. H. W. Lett, rector of Agaderg, co. Down, which though called only a list is a well arranged guide; "A revised Key to the Hepatics of the British Islands" and the "Census Catalogue of British Hepatics," both by Mr. S. M. Macvicar, contain useful lists (published by Sumfield, Eastbourne). "Jungermannideæ Europæ," by Dumortier, in the "Bulletin de la Société Royale de Botanique de Belgique, tome treizième, Bruxelles, 1874," contains a convenient synopsis of the families, tribes and genera as well as a description of the species, and has fine illustrations of the various forms of the spore-cases; "The Synopsis Hepaticarum" of Gottsche, Lindenberg and Nees ab Esenbach (Hamburg, 1844) is a classified synopsis of all Hepaticæ then known in any part of the world and is, therefore, useful for foreign species. "The British Jungermanniæ," by Sir Wm. Jackson Hooker" (1816), is a noble book, both as regards its text and its illustrations, but, of course, out of date as regards classification and minute structure.

Pearson's "Hepaticæ of the British Isles" (1902) is a full systematic account of all British Hepaticæ; it consists of two volumes, one of text and one of coloured plates, and is no doubt the most exhaustive treatise yet published of the British species.

The French Liverworts, which are of course largely also British, are dealt with in a very satisfactory manner in "Muscineés de la France, Deuxième Partie, Hépatiques." by M. l'Abbé Boulay (Paris, 1904). The introductory chapter on the Morphology and Physiology of the group is excellent.

The minute structure and the course of development of this family have been very elaborately studied and illustrated by Prof. Hubert Leitgeb in his "Untersuchungen über die Lebermoose" in several parts (Hefte), dealing respectively with *Blasia pusilla*, the *Foliose Jungermannieæ*, the *Frondose Jungermannieæ*, the *Riccieæ*

Anthocereæ and the *Marchantieæ* (Graz, 1874–1881); and the same subjects have been more recently dealt with in a very satisfactory and interesting manner by Prof. Campbell of California in his "Structure and Development of Mosses and Ferns," London, 1895, and by Prof. Goebel in the "Organography of Plants," Part II., English Translation. Oxford, 1905.

Finis.—To all who may read this little book I can honestly commend the study of the Liverworts. I have endeavoured in the foregoing pages to indicate some of the points of peculiar interest which they have presented to my mind; but they are things not of interest only, but of beauty. Of some forms the elegance and grace meet the eye at once, and it is a charming thing in the springtime to see the banks of some little stream crowded with Liverworts sending up their pellucid pedicels crowned with the black spore-case or the expanded star. And even those forms amongst them which have the least of obvious elegance, are full of hidden beauties that only await the loving observer to give pleasure and joy—

> "those charms minute
> That win their way into the heart by stealth."

It is the office of the naturalist no less than of the poet to call attention to objects that are neglected because they are familiar or obscure, to show the beauty and the charm that lie hidden in common things, to give eyes where there have been no eyes, to dispel the lethargy of the mind and to quicken the spirit to admiration and to love.